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[COMMITTEE PRINT NO. 2]

TITANIUM

STAFF REPORT

SPECIAL SUBCOMMITTEE ON MINERALS,
MATERIALS, AND FUELS

OF THE

COMMITTEE ON
INTERIOR AND INSULAR AFFAIRS
UNITED STATES SENATE
EIGHTY-FOURTH CONGRESS
Second Session

DECEMBER 15, 1956

Printed for the use of the Committee on Interior and Insular Affairs

UNITED STATES
GOVERNMENT PRINTING OFFICE
85069 WASHINGTON : 1956

PURCHASED THROUGH
DOC. EX. PROJECT

FOREWORD

NOVEMBER 30, 1956.

To the Members of the Senate Interior and Insular Affairs Committee:

Since issuance of the original staff study on titanium August 19, 1955, there have been a number of interesting developments which should be brought to the attention of the Congress and the public.

The freeze on the expansion of titanium sponge production facilities to 22,500 tons which was ordered by the Office of Defense Mobilization still is in force. However, as pointed out by Director Arthur S. Flemming of ODM, on August 27, 1956, sponge production has been increased to 31,500 tons by private interests acting independently of the Government.

Whether the freeze was well or ill advised, it seems to me that the Congress and the public should be put into a position to judge. Dr. Flemming also noted on the above date that "a new set of data is now being developed for supply-demand study."

A comprehensive survey has been made of the opinions of sponge producers, mill products producers, fabricators, and end users to determine their point of view as to the sufficiency of titanium sponge in 1956; the adequacy of mill product production; whether the small available supply of titanium and the limited expansion program may be inhibiting use and incorporation in design; and the tendencies toward increased use.

These opinions, plus supplementary additional material which I hope will be helpful, have been incorporated in this supplementary report.

As in the foreword to the August 19, 1955, report I wish to commend my personal consultant on minerals and metals, Bill Broadgate and subcommitee staff members, Robert W. Redwine and George B. Holderer, for their constant research into the titanium picture.

JAMES E. MURRAY, *Chairman.*

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TITANIUM

The Position of Titanium in 1956

The first Senate Interior and Insular Affairs Committee staff study of the titanium situation was published on August 19, 1955. It had a very favorable reception, one large user of titanium mill products saying:

> We agree in principal with the conclusions presented in this report.
>
> We are in complete agreement with the position that "reduction in the cost of titanium mill products will do most to increase the use of titanium," and that integration of operations coupled with development of specialized methods such as extrusions, shear spinning, and close tolerance forgings will result in appreciable cost reduction.
>
> Freer interchange of information will lead to better understanding of and a more rapid solution of the problems encountered in the use of titanium.

The staff report laid considerable stress on the above-mentioned points. The staff report further stated:

> it appears that the demand for titanium will in the near future exceed all expectations—

and

> it appears that from 2 to 3 years are required to put new facilities into full-scale production and it is quite likely that the demands of fabricators and end users may outstrip sponge-making facilities.

Although the new staff survey has been directed toward the immediate situation in 1956, there are many comments in the excerpts from communications to the chairman which go beyond that point and indicate a rapidly growing interest in the use of titanium.

One of the largest producers of titanium mill products may be quoted in part as saying,

> Though developed under military sponsorship, titanium metal now is available for commercial applications. Despite a higher initial cost than many other metals, titanium offers distinct economic advantages where corrosion, weight, or heat is a problem * * * the base plate assembly for the Army 88 millimeter mortar has been redesigned from steel to titanium. As a result, a weight saving of over 40 percent has been made, and 1 man rather than 2, can now carry a mortar base plate. * * * The future of titanium in military aircraft is tremendous. During the transition to jet planes, and now to supersonic craft, many material problems

> have presented themselves to aircraft designers. The solution has been titanium, * * * titanium is replacing both stainless steel and aluminum in aircraft. The weight saved by titanium is being put into increased performance, greater range, greater firepower—keys to air superiority.

In order to justify the use of titanium at present prices—which the committee staff considers still to be excessive—another mill-products producer may be quoted as saying,

> Can any of this (industrial as well as military uses) be justified at today's prices of $10 to $20 per pound for this "noble" metal? Let's take an assembly requiring one-sixteenth inch thick stainless steel, at about 75 cents per pound. This form of titanium costs $14.50 per pound or 19 times more money. But, since titanium weighs only 56 percent as much, the cost factor for enough square feet to make the parts drops to 10.6 times. Because of its higher strength, the titanium probably could be thinner, dropping the factor to perhaps six times. Since the raw material cost is only a small fraction of the cost of the finished assembly, a piece of titanium equipment may cost only 2 or 3 times as much as one made from less costly metals. Obviously, every day of increased life beyond three times that of the previously used metal is money in the bank and some times the life expectancy is many times as long.

The above comment is no doubt true, though perhaps somewhat enthusiastic. A study of the various industry statements printed below indicates that many users do lay a great deal of stress on cost reduction as an important factor in the expanded use of titanium, both for military and commercial applications. Mill-product costs have been reduced since the comment was written, and as the ratios remain generally true it is easy to see that further reductions in price will put titanium in a competitive position.

The subcommittee staff study on titanium was published August 19, 1955. The so-called Vance report is dated July 5, 1955, but did not come to the attention of the committee until it was published patently to support the Office of Defense Mobilization's freeze order of September 12, 1955. The Office of Defense Mobilization order, then, followed the Vance report by 2 months and the publication of the committee staff study by 1 month.

The Vance report, which will be discussed in some detail later, was prepared by Mr. Harold S. Vance, then titanium consultant to the Office of Defense Mobilization. At the beginning of the staff studies which resulted in the committee's titanium report of 1955, Mr. Vance was invited to sit through the entire series of conferences, but he saw fit to attend only one session, although his attendance would have given him an opportunity to obtain firsthand information from all segments of the titanium producing and consuming industry, including military personnel assigned to research projects.

In response to a letter from the chairman dated January 5, 1956, Director Arthur S. Flemming stated, on February 20, 1956:

> We have been keeping close watch on the production and consumption statistics as well as research and development

programs in order to maintain a relatively reasonable balance. A new requirements study, however, will be completed within the next 4 weeks. As soon as that study has been completed, I am going to review the entire matter with the Defense Mobilization Board to see if there should be any change in the conclusions arrived at following the submission of the Vance report.

In the meantime, over a period of several months, the subcommittee staff has been making a survey of titanium-sponge producers, mill-product producers and users of titanium products to determine—

1. How closely they feel availability of titanium products and consumption of titanium products would be in balance in 1956, and
2. Whether the comparatively small tonnage available and the 22,500-ton target for 1958 is inhibiting titanium substitution in present equipment, especially in military aircraft, and in specifying it in future design.

The entire correspondence is much too voluminous to print in this staff report so excerpts have been made which in no way color or slant the opinion of the writer. As a number of the correspondents have asked not to be identified the excerpts following are arranged at random and are keyed to the original letters only by numerals. The reader may form his own opinion of the situation by making an analysis of the excerpts.

EXCERPTS FROM CORRESPONDENCE REGARDING SPONGE AND MILL PRODUCTS PRODUCTION BALANCE

Company 1:

We have been assured by our bar sources that they will be able to supply us with all of the material we need to meet our commitments to the aircraft industry for 1956.

We do not foresee any great unbalance between sponge production and sponge utilization unless the present aircraft engine schedules are drastically revised.

Company 2:

The price of the finished titanium shape is in the cost range of between $15 and $20 per pound for the ultimate consumer.

It is the writer's opinion that, although titanium has many unique properties, its use will not grow to maturity without an appreciable reduction in cost of the material in a fabricated form.

Company 3:

We feel that the use of titanium in airplanes that follow those now entering production will be very large. The availability and the quality of the present sheet, bar, and billet, must be improved, however, for such large-scale use in aircraft.

Company 4:

Our titanium requirements for 1956 will amount to something under 5,000 pounds of commercially pure metal.

Company 5:

In 1956, it is our opinion that there will be relative balance between sponge production and consumption. While this is our opinion currently, requirements for titanium mill products have been increasing rapidly, and I am sure you can understand the difficulty of making accurate estimates with so little history on which to base forecasts.

Company 6:

We believe that there is ample sponge either in being or scheduled to be produced in 1956 to meet all the mill requirements for finished material.

Company 7:

Sponge consumption should see a steadily accelerating rate all throught 1956, and the first quarter of 1957 could readily be as much as 20 percent in excess of the fourth quarter of 1956.

It would be our guess that the titanium-melting requirements in 1956 could call for possibly 9,000 tons or more of sponge to attain estimated finished metal requirements. Looking at Washington estimates of sponge capacity available this year, and assuming the quality to be such as will take care of the specific requirements (we have no reason to fear otherwise), it would appear that in 1956, at least, sponge supply would be adequate.

Company 8:

The 1956 sponge production is considered adequate for the anticipated 1956 consumption of mill and finished products.

This is based on an estimated 1956 sponge production of 8,000 to 10,000 tons, sponge consumption of 6,000 to 7,000 tons and a mill production consumption of 4,000 to 5,000 tons.

Company 9:

	Tons
1954—Titanium mill products	100
Titanium sponge	300
1955—Titanium mill products	200
Titanium sponge	600
1956—Titanium mill products	30
Titanium sponge	90

The jet engines to be shipped in 1956 will contain substantially less titanium than those shipped in the 2 previous years.

Company 10:

Statements to the effect that the demand for mill products in 1956 may reach 3,000 tons do not seem unreaonable judging from the trends of the past several years and the new avenues of demand which have been established.

In order to be conservative and plan enough sponge availability to support 3,000 tons of mill product, I would be of the opinion that at least 7,500 tons of sponge should be available to the melting facilities from either stockpile or current production. As yet, apparently revolving scrap cannot be depended upon for any appreciable contribution to the exacting requirements of current melting. Hence to be sure of not

hampering the provision of 3,000 tons of mill products to the current high standards, the ratio of sponge to products must necessarily remain high.

Company 11:

My estimate of total domestic production of requisite quality sponge in 1956 is 10,500 tons. My estimate of sponge requirements for mill products and finished products for 1956 is 9,000 tons.

It is my considered opinion that in order to maintain the situation in reasonable balance it is important that maximum production of requisite grade quality sponge in domestic installations presently in existence or to be completed in 1956 be given every encouragement.

Company 12:

It is our expectation that this mill will be in operation late in the second quarter of 1957 (Senzimer Planetary Mill).

We would estimate its capacity to be between 500 and 1,500 tons per year (capacities are so dependent upon gage, width, tolerance, grade of metal, and many other factors).

Company 13:

We would conclude that the consumption of sponge will not exceed the sponge production scheduled for 1956; but, by the same token, we firmly believe that the demand for finished products will exceed the supply.

Company 14:

It is our opinion that demand for titanium mill products is not likely to exceed the availability of sponge in 1956.

Company 15:

There has been no indication from our suppliers that titanium needs will be curtailed because of any sponge-production schedule.

* * * our estimate of titanium mill products required for 1956 is 1,300,000 pounds.

* * * tentative requirements for titanium for the Missile Division will build up to approximately 350 tons per month by 1962.

Company 16:

It is our estimate that the production of titanium mill products for the year 1956 will range between 3,500 to 5,000 tons. As to sponge production for the year 1956, we estimate a range of 8,000 to 12,000 tons of production.

* * * there should be an adequate supply of titanium sponge to meet 1956 requirements for mill products.

Department of the Air Force:

On the basis of current requirements estimates for mill products, it appears that sponge production for 1956 will be sufficiently adequate to meet the demand. The Air Force believes that a sufficient margin of safety must be provided in sponge production to compensate for new uses as they develop.

This is particularly important until such time as military applications are proven, the cost stabilized and the potential of this metal more adequately determined. A margin of 100 percent of sponge production in excess of equivalent estimated mill-product use should provide adequate safety, permit the orderly expansion of the industry and yet reasonably limit the obligation of the Government.

Company 17:

We have gained the general impression, without the figures, that production this year will exceed actual consumption.

Company 18:

In the year 1955 we consumed 15,015 pounds. In the year 1956 we anticipate we will consume 103,425 pounds, which represents an increase of approximately 686 percent.

Company 19:

It is my impression, however, that the facilities for sponge production are materially greater than the expected consumption.

Company 20:

I advised that, in our opinion, sponge production will exceed requirements of mill and finished products for the calendar year of 1956.

Company 21:

Without exception, the producers have assured us that sponge will not be a limiting factor.

The bottleneck during 1956 (if one develops) will be double vacuum melt capacity for wrought products ingot, and fabrication capacity for the rolling of titanium sheet.

Company 22:

Based on our market surveys of the business which we expect to obtain during this year, we estimated that our sponge requirements for the year will be approximately 2,300 tons.

Company 23:

We anticipate that during 1956 we will require approximately 4,500 pounds of titanium for * * * use other than subcontract and in addition to this figure we estimate 120,500 pounds for additional work on the * * * subcontract.

Company 24:

We are presently engaged in research work for the use of titanium as a gear material. It is estimated that our contemplated consumption of titanium in 1956 would not exceed 1,000 pounds of mill products. * * * After these designs have been accepted after preliminary testing, an increase above the 1,000 pounds estimated above would be anticipated.

* * * we believe that designers would be reluctant to incorporate into their design the maximum quantities of titanium if they felt that the material would not be available if required. * * * if the material becomes more readily avail-

able and less costly there should be further general use in the field in which we operate.

Company 25:

Based on existing * * * contracts, it is estimated that 15,045 pounds (sheet, bar, etc.) will be used during 1956.

It is anticipated that an additional 43,691 pounds of titanium mill products will be consumed during 1957.

Company 26:

Although * * * usage of titanium mill products will significantly increase for 1956, it is believed that our production requirements for this period will be fulfilled without difficulty and that our overall requirements will have little influence on sponge schedules.

Company 27:

* * * we can see a rapidly increasing demand for mill products, and it is our feeling at this time that sponge production and mill product production will be in relative balance for 1956.

Company 28:

* * * we believe that an adequate supply [of sponge] will be available for the coming year provided that all sponge production facilities operate at capacity, particularly toward the end of the year. It is also our opinion that provided satisfactory quality sponge is available from the GSA stockpile it can be used to supplement production of the presently constructed facilities to meet production needs for 1956.

Company 29:

Our estimate for the year 1956, including both military and a small amount of titanium for our forthcoming commercial jet transport, the DC–8, is 142,143 pounds. This is primarily for sheet stock, with a minimum small bar requirement for a few special forgings.

Stanford Research Institute (*R. H. Thielmann*):

It appears to me that there will be a relative balance between sponge production and metal demands in 1956 and, if the demands should happen to increase a little more than anticipated, the rotating stockpile of sponge would absorb the difference. In short, it is my opinion that there will be enough sponge available in 1956 to make all of the titanium metal in various forms that the industry is capable of using. By 1957, however if requirements continue to increase as planned, the sponge capacity will have to be increased about 25 percent. Whether or not the normal growth of the titanium producers will be able to supply this demand is conjectural, and it certainly should be considered in our long-range planning.

Before the year [1956] is over there are going to be requirements for alloys which require a higher quality of sponge with a hardness in the range of 100 Brinnel or lower. It is my

opinion that consideration should be given to a stockpiling program for high-quality sponge of this type.

Company 30:

While we are not in the commercial fabrication of titanium we have definite interest in that field and have done and continue to do substantial development work in titanium fabrication, particularly regarding extrusions and forgings which appears to us to be in the area in which further efforts are most needed. We also have under investigation the need of the armed services for titanium foil and are considering much needed research and development in that field.

Company 31:

In 1955 * * * 2.3 pounds of titanium sponge were required to produce a pound of mill product. * * * we believe that a good overall ratio would be about 1.5 for the present time. * * * for the present planning the figure should be somewhere between 1.5 and 2.25 pounds of sponge per pound of mill products * * *.

Company 32:

We feel that the restricted titanium sponge production, and more important, the limited titanium mill products production do inhibit the use of titanium in present and future designs.

Even though we be assured that the quality and specifications be satisfactory, as was pointed out in your letter, there is a considerable difference between the quality of mill products of pilot-type production and that of the products of full production. It is because of the recent history of the difficulty in maintaining quality during even a slight increase above pilot production that our designers are somewhat reluctant to take full advantage of improved titanium alloys in their new designs.

In spite of the difficulties mentioned above, we are certain that the proper use of titanium and its improved alloys are necessary to obtain the optimum performance of the next series of combat airplanes.

Company 33:

* * * titanium's strength-weight characteristics, a little over half the weight of steel and roughly equal to it in strength, indicates a bright future in the new light passenger trains, in automobile trim, and in the frames of light trucks.

However, extensive use of titanium for these purposes awaits lower prices. * * * even though titanium is priced about 18 times higher than stainless steel it can compete in some applications now where resistance to corrosion is an important factor.

Company 34:

We have obtained an opinion from our engineering department based on an assumption that the quality of titanium would be satisfactory, but the quantity somewhat limited. Their answer was that the use of this material would un-

doubtedly be curtailed if there was indication of limited availability. This would be particularly true where there was indication of accelerated consumption.

Of interest to you also might be an opinion expressed by our purchasing people to the effect that they anticipate considerable trouble in procuring the quantity of titanium known to be needed for 1956 production.

Company 35:

Your * * * letter suggesting the possibility that designers might be reluctant to incorporate the maximum quantities of titanium, because of the possible scarcity, has been reviewed in detail by our engineering division. A summary of their full report would indicate that regardless of cost or availability, the optimum quantity of titanium to be employed in aircraft manufacture would approximate the following ratios:

By 1960: Approximately 10 percent.

By 1962: Approximately 35 percent, with this latter rate the probable maximum.

Insofar as our designers are concerned, any reluctance to employ titanium would lie less in the fear of insufficient supply, than in the relative costs of the raw material * * *.

It is imperative that a great deal of work be undertaken to perfect manufacturing techniques and accomplish research in the rolling, extruding, forging, machining, heat treat, etc., of titanium before its peculiar requirements can be fully appraised and new tools provided.

Company 36:

There are a number of development programs being discussed in the aircraft industry. * * * the lack of technical knowledge * * * is more of a deterrent to the designers than lack of sponge capacity.

If these, and other like projects, are successful there will be a definite sponge shortage.

Company 37:

It appears inevitable that we will be compelled to use more titanium alloy forgings because of increasing service temperatures. Our program of qualification of the material has progressed to such a point that we no longer hesitate to specify its usage for certain types of applications. However, our commitments are such that we cannot tolerate procurement delays. We have been inconvenienced to some extent by poor delivery to the forge shops. For this reason we have been reluctant to extend our titanium applications.

Company 38:

* * * We have had no direct indication from our customers that the present and projected sponge production is limiting designers' incorporation of this material into future equipment. * * * It is believed that present titanium fabrication facilities are inadequate to meet the demands for mill products.

Company 39:

A review of our present and future programs indicates that application of titanium to our products is not being inhibited by the forecasted availability level of titanium. We are proceeding on new design incorporation on the basis that when our requirements exist in volume the sources for titanium in this country will meet the demand.

Company 40:

Missile performance is predicated on the use of a high-strength, weldable titanium alloy as the primary structural material. Such an alloy is not yet available in sufficient quantity or uniformity to permit its incorporation in design for fabrication. This alloy must be made available by the end of 1956, or a different structural material will have to be used with an accompanying reduction in performance.

* * * * *

A strong Government lead is essential if the development of titanium is to be expedited.

Company 41:

The staff report on titanium issued by the Special Subcommittee on Metals, Materials, and Fuel Economics is an excellent documentation of the titanium situation in the United States. We agree in principle with the conclusions presented in this report.

* * * * *

Freer interchange of information will lead to better understanding of and a more rapid solution of the problems encountered in the use of titanium. * * * You may be sure that the * * * corporation is proceeding as rapidly as possible to carry out its policy of maximum beneficial use of titanium and without restrictions on the basis of metal supply.

We do believe that there is a need for a somewhat closer Government coordination with potentially large users of titanium to insure better accuracy and lead time in anticipating future production demands. Since an adequate metal supply is vital to continued expansion of titanium usage, we recommend a critical review of current methods for predicting industry demands at least 2 years forward.

Company 42:

At the present time, * * * corporation uses no titanium metal in its products * * * if titanium were more generally available, at a price more competitive with the aluminum alloys and, if more reliable information concerning its working properties were available, we would give its use serious consideration. This might result in improved products for our major customers, the Armed Forces.

Under existing conditions, titanium is not easily available, its price is excessive due possibly to the relatively low production required by existing demand and reliable data concerning its properties and methods for working it are not generally available. Hence we hesitate to use it.

Company 43:

Our requirements through 1958 for titanium have been reviewed with our titanium suppliers and we have complete assurance from them that our requirements will be met.

Titanium has excellent physical properties, it is light, and its use will do much to solve the strategic-material problem. Because of this, we are aggressively pushing the use of titanium in our current and future designs of aircraft engines.

The only currently indicated serious problem in connection with titanium is its cost. * * * Presumedly this problem will be overcome eventually by promoting its greater use and finding better ways and means of producing and working the material but a genuine cost improvement would do more to promote the metal than any other possible thing.

Company 44:

It appears * * * there will be no shortage of sponge for the mill production of titanium anticipated in 1956. * * * We do not believe that the limited production of titanium is influencing designers to minimize the incorporation of titanium into design. * * * First there appears to be a serious limitation on the current capacity to produce mill-end items. For example, some of the mills are already "booked" through July 1956. Secondly, although there has been a disappointing delay in the development of suitable high-strength, heat-treatable sheet materials, recent laboratory results appear very encouraging. The successful culmination of this work coupled with widespread interest in this type of material may cause a sudden change in this situation; namely, a critical shortage due to a large demand faced with limited mill and sponge-production capacities.

Stanford Research Institute (*R. H. Thielemann*):

The use of titanium in both engines and airframes is now on a rapidly accelerating curve. * * * The tendency now is to incorporate titanium and titanium alloys in all aircraft applications where the properties are adequate and where the use of titanium provides an engineering advantage.

The Government production goal for sponge of 22,500 tons for 1958, will, of course, be inadequate if the present accelerated rate of usage for titanium is continued.

Company 45:

Our best estimate at the moment leads us to believe that approximately 5,000 tons of titanium mill products will be required in 1956. However, toward the end of the year the requirement rate is expected to be substantially above that figure.

In our contacts with aircraft manufacturers we have not detected any appreciable reluctance to design titanium into present and future applications because of any fear on their part that the product will not be available.

* * * you have asked that we take into consideration the statement in the Vance report that, "when it develops that

presently arranged for capacity will be overtaken by usage, new plants (for sponge) can be put in production in about 24 months, and the need for them can be anticipated by much more than such an interval." We would make two definite comments in regard to this statement: (1) It has not been our experience that the estimates for the use of titanium mill products are sufficiently accurate or given sufficiently far in advance to warrant this statement that they can be "anticipated by much more" than 24 months; and (2) there is some question in our minds whether new plants for sponge can be put into production in about 24 months. It is reasonable to predict that titanium sponge-producing plants can be built and put into operation in 24 months provided the period is not one of full mobilization when other requirements are competing for materials and provided also that the operator is one experienced in the large-scale manufacture of sponge. It is our opinion that only experienced producers could deliver quality output in a 24-month period.

Company 46:

I have made inquiry of some of our engineers, and they have advised me that there is no reluctance on their part to utilize titanium wherever it is advantageous and economically justified.

Company 47:

The current titanium production levels have not inhibited the use of titanium in the high output, high performance jet engines * * * planned or in production. Titanium is being considered on new engine designs wherever its application will give optimum performance. * * * We do not doubt that titanium of adequate quality and meeting specifications can be obtained when required.

Company 48:

Insofar as this company is concerned, the restricted production of sponge or mill products has not inhibited the use of titanium in current production. * * * The problems of fabrication rather than the possibilities of scarcity have held back to use of titanium in airframes, in our opinion. * * * In future designs of airframes I do not find that we contemplate an appreciable use of titanium.

Company 49:

* * * it is our opinion that designers are not reluctant to incorporate titanium into their designs, when warranted, because of any alleged shortage of this material at a future time.

Company 50:

In our work involving the use of titanium we have not been subjected to any inhibitions due to the conditions you outline. Our present designs look forward to production beyond 2 years, and, if the supply picture beyond that point becomes critical, there would be sufficient time to provide the facilities * * *.

Company 51:

It is our opinion that the present limitation on sponge production and mill products is not inhibiting the use of titanium in present or future design.

* * * the fabricators of titanium aircraft parts are now being pushed by designers at a rate greater than fabricating techniques, methods, and practices can be established. Periodically there must be a consolidation of all information and skill, or progress will slow down with alarming rapidity. These technical consolidations, it is believed, will tend to stabilize the demand for titanium production.

We believe that there are many influences which are holding back the widespread use of titanium, which go considerably beyond limitations on sponge production and mill products. We have hopes, however, that the technology of the country will eventually lead to greater employment of this very desirable metal.

Company 52:

* * * our field contact men do not appear to have encountered any hesitancy or apparent reluctance on the part of aircraft designers to consider use of titanium because of concern that the capacity for such product might not be adequate when needed for regular planned aircraft production.

Company 53:

* * * titanium for a large-scale program would seem to be sufficiently well assured so that this factor should not inhibit the use of titanium in present and future design.

Company 54:

Our conclusion is that a presently restricted sponge program should not be a deterrent to design.

Company 55:

Our designers have not specified titanium for use in our current production of aircraft. This is due to the type of aircraft and not to any restrictions on the production of titanium sponge or mill products.

Company 56:

Our design work proceeds with the expectation that our orders will be filled when they are placed.

In our current design work, we are presently increasing our usage of titanium whenever this material is judged to be uniquely more suitable for an individual component than other materials of construction. This design philosophy is applied in our military designs as well as in our commercial activities.

Company 57:

It is my impression that designers would be eager to incorporate titanium if they were assured and confident of the qualities upon which titanium has been promoted as a structural material.

The development of well-established uses for titanium metal will probable take place in the fields where its use can be justified on a basis of unique chemical properties rather than its purely mechanical aspects. We must look for these fields of application to emerge from the new technologies.

Company 58:

No matter how good the physical properties of titanium are and no matter how reliable the physical properties of the material supplied, the use for titanium in large quantities depends on a substantial price reduction. I refer particularly to a price roughly twice the price of aluminum.

If the titanium industry could make such a price reduction, then it is my opinion that titanium will be used in great quantities and we can envision, in 20 years, an industry not unlike that of stainless steel.

Company 59:

We have had our * * * representative confirm * * * the figure of 14,000 tons (sponge production estimated for 1956). This lower figure merely paints a worse picture than was indicated with the original figure. Again emphasizing that our consumption rate is not necessarily indicative of the industry as a whole, we still must start on some basic assumptions. We therefore discounted our increase in use of titanium by 50 percent and with the new 14,000 tons anticipated production capacity indicates an inadequate supply being programed, amounting to 108 percent or 8,700 tons. If this is anywhere correct, it would appear that our purchasing department will be in for a rough time in 1956.

Company 60:

Our estimated mill products requirements for titanium this year is 370,000 pounds. This includes material purchased both by (this company) * * * and its subcontractors.

Company 61:

* * * I do not feel that restriction of either sponge or mill products is acting to inhibit the use of titanium in present or future design * * * the production of mill products is still lagging behind sponge production * * * it has been my impression that there are still uncertainties regarding quality of products, especially at higher temperatures.

Company 62:

The designers of our products are not hesitating to incorporate appropriate usage of titanium alloys in their designs because of critical quantity limitations.

* * * our titanium requirements are estimated to be as follows: 1955, 8,300 pounds; 1956, 5,900 pounds; 1957, 10,500 pounds.

Company 63:

We do not believe that the sponge production of 14,000 tons for the year 1956, nor the production of seven to eight

thousand tons of mill products for the same period is inhibiting the use of titanium in present and future designs.

Company 64:

Our present impression is that the hesitancy on the part of the airplane designers to go all out in incorporating titanium in their designs is due not only to their doubt as to adequate capacity presently available for sponge production, but more directly to their lack of confidence in the quality of the mill products, particularly sheet, that would be available to them in any substantial quantities.

* * * potential users * * * concern today is related more to existing fabricating capacity * * * that fabricating equipment and know-how have not kept pace with the progress potential of the industry.

There is a cloud over the whole situation, also, arising from the feeling that the Government is holding back on authorizing additional sponge-production capacity in the belief that better and less costly methods than the ones now in use, or proposed, can and will become available within the not too distant future.

TITANIUM FOR MISSILES

Company 65:

Missile performance is predicated on the use of a high-strength weldable titanium alloy as the primary structural material. Such an alloy is not yet available in sufficient quantity or uniformity to permit its incorporation in design for fabrication. This alloy must be made available by the end of 1956, or a different structural material will have to be used with an accompanying reduction in performance.

Company 66:

Based on our production experience and the production use of A–110AT by three of our important customers, we are certain that the quality and uniformity will be adequate and that sufficient material can be made available for missile applications.

Company 67:

We now believe that rather good alloy sheet will be available well before the end of 1956. This sheet will not be completely satisfactory, but will rather readily permit them to go ahead with prototype production of missiles.

Company 68:

For well over a year we have been aware of this problem * * *. Based on this work we believe this alloy to have a good chance of meeting these specifications.

Up to this time the titanium industry has spent its own money in the development of titanium alloys suitable for aircraft applications including the missile program. Recognizing the importance of this structural material from the standpoint of time, the titanium industry a year ago recommended and strongly urged the immediate adoption of a Government-sponsored titanium sheet-alloy development program. Had

this program been initiated then, it is possible that the titanium alloy referred to in your letter would be "available by the end of 1956."

It will be remembered the Vance report blithely assumed about titanium:

1. Its availability in sufficient quantities is assured;
2. Improved quality and uniformity have been achieved;
3. Fabrication processes have been made commercial; and
4. Costs have been substantially reduced.

COMMENT ON VANCE ITEM 1

"*Its availability in sufficient quantities is assured*"

Mr. Vance estimated that the consumption of titanium sponge for the years 1955 through 1957 would be 32 percent of production. Yet in 1955 about 1,900 tons of mill products were made which consumed about 3,800 tons of sponge, or 52 percent of the sponge production for that year. All reports indicate a rapidly upturning consumption curve for mill products during 1956 and there is some opinion that sponge and mill-product production soon may be in balance. There is, of course, a backlog of sponge held by General Services Administration, which would prevent an actual shortage in case of emergency.

It seems to the subcommittee staff the fact that 1 sponge producer has announced an expansion program from 3,600 tons per year to 6,000 tons per year at its own expense and several other programs, including one from 3,600 to 7,200 tons, have been initiated, is sufficient indication that the titanium industry feels the expansion goals set by the Office of Defense Mobilization are woefully unrealistic.

TITANIUM METALS CORP. COMMENTS

Below are some interesting remarks by the Titanium Metals Corporation of America showing its advances in the 12 months prior to August 1956.

A. Advances in titanium production in last 12 months:

1. Operations in sponge have been at capacity with an output of 7,945,000 pounds.
2. Operations in mill products have been at capacity since January 1, 1956.

B. Major advances in technology in the last 12 months include—

1. Reduction in average Brinell hardness of sponge to approximate level of 125 compared with contract guaranty (revised) of 170.
2. Introduction on commercial scale of two new sheet alloys Ti–140A (low strength, high formability product) and Ti–6A1–4V (heat treatable, high temperature product); solid and hollow extrusions; titanium powder.
3. Development of a new alloy sheet now in large-scale evaluation under the Department of Defense sheet-rolling program.
4. Commercial production of largest titanium ingot in use anywhere, approximately 6,000 pounds.

C. New facilities:

1. Placing in partial production expanded sponge facilities rated at 6,000 tons per year. To be completed by December 31, 1956.

2. Placing in partial production expanded melting facilities. To be completed by December 31, 1956.

3. Placing in partial production expanded mill-processing facilities.

4. Placing on order Senzimer mill to produce strip of closer gage tolerance and better surface in widths to 48 inches.

5. Initiation of program to expand melting facilities to 11,000 tons per year and sponge to 9,000 tons per year and mill-processing facilities to convert the ingot to mill shapes, to be in operation by December 31, 1957.

Although you have not asked for this information, you may be interested in the trend of sponge prices as follows:

November 1955, from $3.95 to $3.45 per pound.
May 1956, from $3.45 to $3.25 per pound.
August 1956, from $3.25 to $3 per pound.
December 5, 1956, from $3 to $2.75 per pound.

Reduction in mill product prices were as follows:

November 1955, approximately 9 percent.
May 1956, approximately 6 percent.
December 3, 1956, 6 to 8 percent.

* * * * *

Mr. Vance stated:

My first recommendation is that no Government assistance be given for creation of additional sponge capacity, and that all pending negotiations with respect thereto be suspended. When it develops that presently arranged-for capacity will be overtaken by usage, new plants can be built and put into production in about 24 months, and the need for them can be anticipated by more than such an interval.

Perhaps new Government plants can be built and put into operation (after 6 months to a year's negotiation with the Government) but was the need for them being properly anticipated? This question seriously agitated the subcommittee staff until the announcements of expansion with private funds. It appears as though Mr. Vance seriously underestimated the upturn in mill-product consumption.

Industry has been more farsighted and has arranged without Government stockpile contracts to keep sponge production abreast and ahead of mill-product production.

The Air Force has informed the subcommittee that it is its opinion that sponge-production facilities should be kept 100 percent ahead of mill-product requirements, presumedly until the situation stabilizes.

While the Office of Defense Mobilization stands pat on a target which evidently is obsolete (22,500 tons of sponge in 1958), we are encouraging Japanese expansion by purchasing Japanese titanium sponge (of excellent quality). England and France are expanding their respective sponge capacity (the English have cut the price below United States figures) and there has been a press statement of ques-

tionable accuracy to the effect that Russian production may be as high as 90,000 tons per year. This estimate of Russian production is based upon the amount of titanium ores being consumed by the Soviets. It seems unlikely that such large quantities of ores are being used to make pigments. However, no agency of the Government is able to inform the subcommittee how much titanium is being designed into Russian military or other aircraft.

In fact, one high-level agency reported:

> In recognition of the seriousness of the situation resulting from the paucity of information on titanium production and use in the Soviet bloc, this Agency convened a meeting of titanium specialists from various other Government agencies. The consensus of the group was that there existed a governmentwide shortage of information on Soviet titanium developments. It was also unanimously agreed that the extreme degree of secrecy covering titanium information reflects the importance placed on titanium by the Soviets.

A later analysis of the Soviet situation follows:

> According to a press article in Promyshlenno-Ekonomicheskaya Gazeta (Industrial-Economic Gazette) dated July 1, 1956, titanium electrodes up to 80 millimeters in diameter are in use in the U. S. S. R. Our industry uses electrodes about twice this size. We are rolling ingots of titanium of 1 to 2 tons. We believe that the Soviets have only recently been able to roll one-half to 1 ton ingots.
>
> Since our first letter on this subject, we have convened a second governmentwide conference on Soviet titanium developments. The conclusions of this conference were as follows:
>
> (*a*) The Soviet titanium industry as of June 1956 may have reached a small-scale commercial production.
>
> (*b*) Information available to date is too fragmentary to base a quantitative estimate of titanium production in the U. S. S. R.
>
> (*c*) Evidence of Soviet utilization of titanium metal and alloys in aircraft or for other applications is lacking except for experimental work. Of course, ferrotitanium is used in steel manufacture.
>
> We have found a reference to titanium technology in the East German literature which will be of interest to you. In the Zeitschrift Chemie-Ingenieur-Technik, No. 4, 1956, reference is made to experiments "on a technical scale" for production of titanium sponge by a modified Kroll process (reduction takes place in vacuo instead of in a noble gas atmosphere) at the Bitterfeld plant of V. E. B. Electrochemisches Kombinat. This plant is well-chosen for the experiments in the light of its extensive experience in the production of magnesium.

TOO LITTLE AND TOO LATE?

It seems to be indicated that the Vance report may have been much too conservative and that the Office of Defense Mobilization should

have weighed it more carefully before embarking on a course which conceivably could result in the Russians achieving performance superiority in military aircraft and in the guided missile field. Certainly, in such a vital area of military preparedness, it is far better to have too much rather than too little.

The subcommittee staff definitely has been disturbed by these questions:

> Did the 22,500 ton sponge limitation, coupled with the "freeze" placed upon the expansion of sponge facilities pursuant to the Vance recommendations, inhibit the substitution of titanium for other metals into aircraft and military equipment now being built, and from designing the metal into aircraft and other military equipment now on the drafting board?

There is a strong indication that this may be so as availability of material is an important factor in design, although some of the correspondence does not bear out the supposition. Should large quantities of titanium be designed into a plane which was suddenly ordered into mass production, the situation could become very embarassing and costly if the construction of facilities lagged behind for several years. Designers of military aircraft would be especially sensitive to this condition.

One of the largest users of titanium in aircraft informed the chairman:

> We agree with you that any expectation of quantity shortages at the critical time would be a strong deterrent against maximum use of titanium in future aircraft designs.

Nearly all the answers to the subcommittee surveys indicate expanding use in a rapidly upturning curve.

The subcommittee staff got the distinct impression from the Army that, as tanks and similar equipment would require vast quantities, the restricted output as well as the cost was holding back utilization. It must be remembered that the output of sponge for 1956 is estimated at a maximum of 15,000 tons and of mill products at about 5,300 tons, not very encouraging figures for the designer of heavy equipment. It may well be that the "freeze" on sponge is self-limiting and is curtailing usage of finished products.

One company, a large user of titanium products, has assured the subcommittee that—

> The bottleneck during 1956 (if one develops) will be double vacuum melt capacity for wrought products, ingot and fabrication capacity for the rolling of titanium sheet.

It is of course true that the considerable backlog of stockpiled sponge will prevent a real shortage developing in 1956 but there is some question as to the quality of the products which can be made from this sponge as compared with more recent production.

The subcommittee staff still feels that substandard sponge should be released to industry at reduced prices for use in applications not as demanding as aircraft so that industrial equipment manufacturers will be induced to get the "feel" of the metal, and the storage costs

will be eliminated on this early substandard sponge. The Office of Defense Mobilization is discussing some plan for the "exchange" of this older sponge.

1957 A CRITICAL YEAR

The Curtiss-Wright Corp. has informed the subcommittee as follows:

> The picture for 1957 does not appear as good since the demand is apparently increasing more rapidly than predicted expansion of sponge and melting capacity. The demand for mill products is conservatively estimated at about 10,000 to 12,000 tons for 1957 whereas supply is estimated at 10,000 tons based on sponge capacity of about 28,000 tons. The latter sponge capacity requires almost a threefold expansion between this year and next and it appears to us quite optimistic to expect that the added capacity required will be completely on schedule. It is therefore our opinion that the predicted output of 10,000 tons of mill products for 1957 is also somewhat optimistic.
>
> It should be pointed out that even at present when mill-product capacity is able to accommodate the demand it is still necessary to order titanium to a melting schedule which involves excessively long lead times for the aviation industry. It is our suggestion that inquiries be directed toward the possibility of providing for reasonable inventories of titanium in ingot form in order to shorten this lead time.

COMMENT ON VANCE ITEM 2

"*Improved quality and uniformity have been achieved*"

That improved quality and uniformity have been attained is definitely true and great steps in this direction have been achieved since the Vance report was issued. However, in the case of sponge, the subcommittee is informed that the newer alloys will require 100 Brinnel sponge. 120 Brinnel sponge now is quite commonly produced but no 100 Brinnel in any quantity. To quote one of the smaller but rapidly expanding sponge producers:

> Another significant step has been our improvement in quality. A year ago we were having difficulty maintaining the carbon content of our metal below the specification of 0.07 percent. At the present time our carbon is averaging less than 0.04 percent. This has resulted in a significant reduction of the Brinell hardness of our metal—all the other impurities are well below accepted maximum levels. We are confident that during the next few months further reductions in impurities will be realized—

and a large sponge producer states:

> Concurrently, the quality of the sponge has been improved in respect to iron content and Brinell hardness.

With increased double-vacuum melt capacity, additional Senzimer mills and other mill products production facilities, both quality is improving and quantity will be increased. There still is some indi-

cation that under certain conditions mill-product volume may fall behind demand, if not in 1956, then in 1957, and that some consumers show concern about the situation.

The desirability of having integrated facilities as pointed out in the August 1955 report was emphasized in December 1955 when one of the largest producers of titanium ordered a rolling mill especially designed for working titanium with the announcement that—

> integration of melting and rolling facilities under a single management was the next logical step in gearing up to meet the rapidly increasing demand for titanium mill products.

Such integration will enable this company to directly control all stages of titanium production from sponge blending through shipment of finished sheets, strips, bars, plates, etc., and will assist in smooth scheduling and uniform quality control. In this connection North American Aviation states:

> It is perhaps appropriate to acknowledge the action of the Department of Defense in establishing the titanium sheet-rolling program, which will facilitate the development and evaluation of improved titanium alloys for aircraft—

and Chance Vought Aircraft, Inc., remarked:

> Notwithstanding an extension of procurement lead times of from 4 to 5 weeks caused by the steel strike, we believe that the major contributor to the original long procurement lead time of 9 months was and is now a lack of adequate facilities and associated equipment assigned to its manufacture.

As another example of the forward movement in titanium fabrication it is noteworthy that the Titanium Metals Corp. has placed an order for $3 million reversing cluster mill for the cold rolling of bands of titanium sheet in widths up to 49 inches. It is claimed that this machine will roll to extremely close tolerances and give the sheets a mirror finish. Since titanium became an important factor in the metals business, metallic titanium has been rolled and forged on equipment designed for stainless steel. Titanium Metals Corp. has announced that order tonnages now have reached the point where the engineering and building of major conversion equipment particularly adapted to the characteristics of titanium is warranted.

The progress toward complete integration and specialized equipment will result in better and more uniform products and, definitely, in additionally lowered costs for mill products.

COMMENT ON VANCE ITEM 3

"*Fabrication processes have been made commercial*"

It is not easy, if possible, to interpret just what Mr. Vance meant by this statement as fabrication processes were made commercial long before his report was issued. He might just as well have observed that—

> It has finally been determined that rutile can be converted into metallic titanium.

That fabrication techniques have improved remarkably and still are advancing rapidly is unquestioned.

However, the subcommittee still notes many complaints that know-how is not sufficiently availabile, in spite of the Battelle Memorial Institute project. It will be remembered that the subcommittee staff laid great stress on dissemination of know-how at the shop level and it appears there still is a lack in this area.

The Department of the Air Force informs the chairman that it is issuing contracts to industry which, although primarily designed to improve fabrication techniques, will also increase the use of titanium in both present and new model aircraft as well as provide designers with essential engineering data. These contracts are listed below:

Titanium projects

Contractor	Cost	Scope
Ryan Aeronautical Corp.	$272,000	Formability and welding of titanium alloy sheet.
Harvey Machine Co.	607,000	Development of production technique for extruding titanium.
Wright Aeronautical Corp.	1,435,000	Substitution of titanium for other metals in J–65 engine. (This project included in Mar. 30, 1955, report as being under negotiation.)
North American Aviation, Inc.	1,866,905	Development of fabrication methods and manufacturing techniques for using titanium in Navaho missile.
Western Gear Works	153,096	Development of titanium gears.
Northrop Aviation	180,637	Establishment of design criteria and development of production methods for manufacturing titanium fasteners.

In addition, as early as February 1, 1956, negotiations were underway for the letting of additional contracts of a similar type in the sum of $1,725,000.

The Air Force further states:

> With respect to the designing of titanium into new models, the Air Research and Development Command was directed in August 1955 to take necessary steps to encourage designers to use titanium where it is feasible. In this connection, it is believed that the improvement in the quality of the mill products during the past 6 months will in itself influence designers to use additional quantities of titanium.
>
> Additional projects under consideration by the Air Force include—
>
> 1. Development of manufacturing techniques for producing titanium castings.
> 2. Development of suitable resistance heating and production techniques for hot riveting of titanium.
> 3. Improvement of existing forging techniques for the purpose of obtaining better quality and material utilization.
> 4. Improvement of existing extrusion processes including investigation into die life, lubricants, and better surface finish.

All this is most encouraging, and it seems to the subcommittee staff that there is a definite awareness in the Air Force of the necessity for gaining additional know-how so that the use of titanium can be rapidly expanded. At the same time this awareness does not always extend to the bottom echelons. In answer to a request for an experimental tita-

nium contract, directed to Wright-Patterson Air Force Base one applicant for information received the following reply:

> We wish to thank you for your inquiry of February 27, 1956, concerning research work on the machining of titanium.
>
> At the present time, we know of no requirements for research work on the machining of this metal. However, we are forwarding your letter to Mr. B. F. Blizzard, MCPMRP, who will in all probability handle the procurement of research and development work if and when such a requirement exists.

Supplementary list of naval titanium development projects, Aug. 23, 1956

Description	Contractor (a naval activity)	Value	Status
Development of titanium hydrofoils	Not yet selected	[1] $45,000	Proposed.
Engineering of electrolytic process for production of titanium.	Horizons, Inc	206,000	Current.
Accumulation of design data for titanium sheet rolling program.	Battelle	69,000	Proposed.
Welding, brazing, and bending techniques for fabrication of titanium alloy sandwiches.	Not yet selected	40,000	Do.
Heat-treating procedures for selected titanium alloys.	do	25,000	Do.
Titanium alloys for 20-millimeter Mark 7 feeder parts.	Naval Gun Factory		Current.

[1] May expand to $150,000 a year.

Mr. John H. Garrett, of Research and Development, Office of the Secretary of Defense, said on March 6, 1956:

> There are about 200 such research and development projects currently in existence and an additional four-hundred-odd projects have been completed. From these projects, approximately 1,400 reports have been collected.

He also remarked—

> In spite of the accelerated degree of acceptance of titanium, we are only on the threshold of development and use of this metal.

Although the subcommittee staff investigation indicates there is room for great improvement in fabricating techniques, it also appears that many present methods are reasonably satisfactory and are constantly being improved.

COMMENTS ON VANCE ITEM NO. 4

"*Costs have been substantially reduced*"

Mr. Vance states that costs have been substantially reduced. It is presumed that he refers to the cost of sponge and mill products. Although it is true that sponge costs have been reduced (see p. 16), the subcommittee staff does not feel that the word "substantial" is warranted, especially when mill products costs are considered. Solar Aircraft Co. reports:

> While we are constantly striving to develop new methods of manufacture which will result in lower costs to the ultimate user of titanium products, the progress being made in the mill processing inevitably affects our progress in fabrication.

> We feel that the recent price drops in raw titanium metal is very encouraging. However, it should not be presumed that the cost of materials such as sheet, bars and forgings will drop noticeably in proportion. A great deal of the selling price of titanium and its alloys is due to the high fabricating costs. Rolling is extremely difficult in many of the alloys, and it has been reported that actual loss in the mill can run as high as 55 percent.

The cost spiral begins with the manufacture of titanium tetrachloride under present methods of manufacturing titanium sponge. A reduction in cost of tetrachloride of 1 cent per pound results in a reduction of about 4 cents per pound of titanium sponge. As the tetrachloride is made from rutile the cost of rutile is a basic factor. Realizing the relatively high cost of rutile and tetrachloride the Bureau of Mines is instituting a program of experimental work to find a satisfactory way to make titanium tetrachloride with ilmenite as a basic material. As may be noted from the figures below which were compiled as of February 28, 1956, the cost of rutile is about 30 percent of the total cost of production.

(*Production cost of 1 pound $TiCl_4$ (titanium tetrachloride)*

[Composite of costs from several companies; complete data from one company not obtainable]

	Cents
Rutile (0.5 pound at 7.5 cents)	3.75
Chlorine (1 pound at 3.0 cents)	3.00
Labor	1.50
Power	.50
Maintenance	1.50
Depreciation	1.60
Miscellaneous	.40
Total	12.25

In April 1955 Dr. H. H. Kellogg wrote:

> Prices of titanium metal products have remained high not because they are close to the minimum costs attainable with the Kroll process and current practice in consumable-arc cold-mold melting, but because of the infant nature of the industry.

Dr. Kellogg predicted an eventual price of $1.15 per pound when annual United States production reaches around 200,000 tons per year with integrated plants especially designed for handling titanium of 20,000 to 40,000 tons per year capacity. Then, he feels, the price of ingots will come down to $1.30 per pound and the average price for mill products will approximate $2.09 per pound. Although this is peering a long time into the future, the subcommittee staff feels that sponge, ingot, and mill-product prices further could be considerably reduced in 1957. The Kellogg figures, of course, would put titanium squarely in a competitive position costwise with other light metals, considering its desirable qualities.

If the present upturn in mill-products consumption continues in the same rate of acceleration the Kellogg figures may be approximated much sooner than he has expected.

It will be noted that a number of the companies writing to the subcommittee stress the high-cost factor as inhibiting the use of titanium

in their products, rather than availability and quality. The price in Japan and in England is lower than the United States price but this no doubt is largely due to the labor-cost element.

It might be interesting to detail the cost of making titanium sponge on a pilot-plant basis. Bureau of Mines Report of Investigations 5248 details of the costs of making about 1,350 pounds of titanium sponge per day as follows:

DIRECT OPERATING COSTS

Table 2 itemizes the direct operating costs for March 1954 and also lists the cost elements considered herein to be direct operating costs. Table 3 lists the quantitative operating data for the major items. March was chosen for detailed presentation because it was typical of about 7 months' operation, during which production was stabilized and was not influenced by starting-up, expansion, or closing-down factors. Before October 1953 operations were influenced by employee training, schedule testing, and expansion of facilities. After May 1954 production was influenced by the nearing fulfillment of the contract and subsequent shutdown.

TABLE 2.—*Direct operating costs for March 1954, Boulder City titanium plant*

	Cost	Cost per pound of titanium
Titanium tetrachloride	$73,470.03	$1.746
Magnesium	18,009.41	.428
Total raw materials	91,479.44	2.174
Operating labor	18,235.75	.433
Repair labor	5,633.14	.134
Supervision	2,980.60	.071
Total labor and supervision	26,849.49	.638
Mechanical supplies	4,058.98	.096
Operating supplies	2,350.32	.056
Pot and retort depreciation	2,825.12	.067
Helium	2,125.20	.051
Total supplies	11,359.62	.270
Power, distillation furnaces	560.14	.013
Power, all other	253.29	.006
Propane, $TiCl_4$ stills	135.14	.003
Propane, reactors	572.61	.014
Propane, dry room	719.18	.017
Water	52.45	.001
Total utilities	2,292.81	.054
Office overhead	970.00	.023
Laboratory labor and supplies	1,571.53	.037
Total overhead	2,541.53	.060
Grand total	134,522.89	3.196

GENERAL INFORMATION ON TITANIUM

Expansion of titanium production abroad is quite notable and the following figures and comments on Japanese titanium production and United States imports of titanium sponge should be of interest. These figures were compiled as of February 27, 1956.

Japanese titanium

Estimated annual production in tons based on 11 months—January–November 1955:		Estimated annual production in tons based on 3 months—September–November 1955:	
Osaka	604	Osaka	918
Taho	576	Taho	738
Nippon	111	Nippon	150
Nihan	10	Nihan	7
Mitsui	8	Mitsui	5
Total	1,308	Total	1,818

Imports into the United States

	Tons
1954	400
1955	470

Monthly importations, 1955

	Pounds		Pounds
January	69,833	July	27,282
February	84,413	August	122,939
March	54,836	September	71,262
April	88,233	October	140,149
May	97,445	November	102,748
June	82,399		

The price with 20 percent ad valorem tax paid is just a shade under the domestic price of $3 per pound.

The three principal consumers of Japanese sponge have been Rem-Cru, Mallory-Sharon, and Republic.

Information from the Commerce Department on the purchases is as follows:

> Receipts of Japanese sponge during the 5-month period January to May 1955, totaled 364,632 pounds, and was divided into Brinell hardness grades as follows:
>
> | BHN: | Pounds |
> |---|---|
> | Below 110 | 93,000 |
> | 110 to 119 | 216,700 |
> | 120 to 129 | 21,932 |
> | 130 to 139 | 20,000 |
> | 140 to 149 | 10,000 |
> | Above 150 | 3,000 |
> | Total | 364,632 |
>
> The reasons given by these three companies for their purchase of Japanese sponge were:
>
> 1. Evaluation of material.
> 2. Special quality required for blending and to permit greater scrap additions.
> 3. Price advantage (not applicable in all cases).
> 4. Shortage of low Brinell sponge in this country at that time.
>
> As you know, the domestic producers are now producing sponge which averages well below 130 BHN, and in quantities sufficient to meet the demand. We do not believe that the importation of sponge for commercial use will continue at the 1955 rate during this year but the receipts of Japanese material on the barter-deal contract will increase total imports above the estimated 500 tons in 1955.

Mallory-Sharon and Republic have been principal buyers. It is believed they will go back entirely to DuPont and Titanium Metals sponge since the quality has greatly improved.

When the subcommittee staff report of August 19, 1955, was written, the schedule for titanium sponge production under Government-sponsored projects was as follows:

Titanium sponge—Capacity expansion contracts

[Productive capacity shown as tons of production of titanium sponge by years until capacity has reached contracted for 22,500 tons]

Contract No.	Contractor	1955	1956	1957	1958
DMP-6	E. I. du Pont de Nemours & Co	[1] 3,600	[1] 3,600	[1] 3,600	[1] 3,600
(D)-12047	Titanium Metals Corporation of America	3,600	3,600	3,600	3,600
DMP-75	Cramet, Inc	800	5,750	6,000	6,000
DMP-90	Dow Chemical Co	85	915	1,800	1,800
DMP-100	Union Carbide & Carbon Co	0	2,000	7,000	7,500
Total		8,085	15,865	22,000	22,500

[1] Du Pont's privately financed facility, 900 tons; Du Pont expansion under above contract, 2,700 tons.

Actual production for the year 1955 by months and companies was as follows:

Titanium production, 1955

[Pounds]

Year 1955	Du Pont	T. M. C. A.	Cramet	Dow
January	538,000	625,428	----------	8,320
February	544,000	575,854	16,197	13,429
March	556,000	621,914	37,367	11,727
April	564,000	662,000	61,997	17,719
May	612,000	691,623	66,959	[1]
June	546,000	738,045	82,554	35,716
July	528,000	479,272	112,102	[2]
August	620,000	540,246	69,824	28,689
September	528,000	712,811	125,476	369
October	438,000	593,763	151,569	10,207
November	284,000	479,456	145,419	15,415
December	424,000	639,317	164,712	4,796
Total	6,182,000	7,359,729	1,034,176	146,387

[1] Increased amount of titanium in process, unable to finish.
[2] Due to start-up operation of expanded facility in July.

The total United States sponge production for 1955 was 7,361 tons and the estimated production for 1956, 14,115 tons in Government-sponsored projects. An excellent illustration of the optimism of industry for the future of titanium is the announced expansion of Titanium Metals Co. from 3,600 tons of sponge per year to 6,000 tons per year, and Du Pont from 3,600 tons to 7,200 tons without Government aid. These projects call for full production by the end of 1956.

A recent statement by Mr. Thomas H. Miller of the United States Bureau of Mines is to the effect that—

> The light metals, aluminum, magnesium, and titanium have increased in importance within the framework of our domestic economy as is evidenced by the increased production and the new applications of these metals being currently reported.

Mr. Miller also stated:

> The Bureau will initiate a comprehensive program of field work to delineate and evaluate the titanium resources of the United States and will expand its research on the extractive metallurgy of titanium, including electrolytic purification.

It will be noted that the Soviets have to depend upon ilmenite as a basic material for the production of titanium, whereas our processes are based upon imported rutile as the raw material. There is no doubt but that the United States resources are principally ilmenite, and more experimental work should be done by industry and the Government to find an economic method of utilizing this mineral.

As a further indication of the importance assigned to titanium by the Russians, on April 2, 1956, the following statement was radio broadcast from that country, one of the few references to titanium heard from the U. S. S. R. recently:

> The importance of the eastern areas in the matter of supplying the country with nonferrous and rare metals as well as minerals increases in the years of the sixth 5-year plan. To fulfill the great program of increasing the output of the nonferrous metal industry, it is essential, in addition to making better use and expansion of existing enterprises, to build many new major enterprises. In this connection, the volume of capital construction in the nonferrous metal industry in the sixth 5-year plan will be 2.3 times more than during the fifth 5-year plan. With minor exceptions, the construction of the new enterprises manufacturing aluminum, manganese, titanium, copper, zinc, tin, and many other nonferrous and rare metals as well as minerals will be in the eastern areas of the country rich in supplies of these metals.
>
> In connection with the rapid development of industry and the immense scale of capital construction in the remote and frequently uninhabited eastern areas of the country, one of the most important problems is the question of providing manpower for these areas. During the sixth 5-year plan alone, the number of workers and employees of the eastern areas will increase by approximately 3 million people, which will comprise nearly one-half of the total increase in workers and employees throughout the country.

As of July 31, 1956, the status of the various titanium projects under the General Services Administration program, as reported by that agency to the subcommittee, was as follows:

ACTIVE NEGOTIATIONS

1. *National Distillers Corp.*—This proposal calls for support by the Government of a ton and one-half per day installation designed to prove the feasibility of the company's sodium reduction process. The support would take the form of providing a market for 1,000 tons of titanium sponge over a 2-year period from the date the facility is completed at market price. It has received ODM and MAB approval and we are waiting upon National Distillers Corp. to commence negotiations. The company has temporarily been absorbed

with other activities but it is expected that its representatives will be in touch with us in the near future.

In the last report, which was prepared as of February 3, reference was made under the heading "Active Negotiations," to a proposal from Western Pyromet Co. and one from Columbia Southern-Imperial Chemical Industries, Ltd. Since that date both proposals have been declined as not consistent with the latest directives from ODM to the effect that further Government financial assistance to bring about expanded capacity shall not be granted and that pilot operations should be assisted only where new processes or substantial variations to the Kroll process are involved.

In prior reports we had referred to a proposal for pilot plants submitted by the Grace Chemical Co. Careful consideration showed that the Bureau of Mines had already anticipated much of the work contemplated in the proposal, and it was accordingly declined.

EXECUTED CONTRACTS

1. *DMP–75, Cramet, Inc.*—The last report showed that the Crane Co. had requested permission to sell half of its interest in Cramet, Inc., to Republic Steel Co. Since that date the consent has been granted, and we are informed that the transaction has been completed. As a part of this arrangement, the contract has been amended to provide more favorable conditions to the Government should the plant be turned back for reasons of obsolescence or operating losses. The contractor has been steadily improving the quality of its production. Through June 30, 1956, the Government has accepted approximately 1,200 tons of sponge under the terms of the contract.

2. *DMP–114, Horizons, Inc.*—This was a contract to pilot the contractor's process for scrap recovery. It was extended through April 30, 1956; has now been completed; and the report is in process of analysis.

3. *DMP–99, Dow Chemical Co.*—While through June 30, 1956, the Government has accepted only 229 tons of sponge from this contractor out of a total of 1,000 tons called for in the contract, we are informed by representatives of the contractor that a total of approximately 350 tons have been produced, the remainder being in process of sizing, analysis, etc., preparatory to tender by the contract date, September 1, 1956.

4. *DMP–113, National Research Corp.*—The prior report showed that the pilot plant installation had not been completed. This now has been accomplished, and the contractor is engaged in the operational phase of this effort. Technical difficulties have developed from time to time, but it is the opinion of the contractor and that of MAB, which recently inspected the installation, that the work will be completed within the time and funds available. No prediction can be made as to the success of the undertaking.

5. *DMP–115, Wah Chang Corp.*—This contract, which called for the purchase by the Government of up to 70 tons of sponge to be produced incident to the contractor's experimental operations at the Boulder City, Nev., facility of the Bureau of Mines, has terminated with 69 tons having been delivered. The contractor has requested an extension for another year, or until June 30, 1957, during which time the Government would take up to 120 tons of maximum 115 Bhn sponge. ODM approval has been sought and is awaited, after MAB approval was obtained.

6. *DMP–100, Union Carbide (Electro Metallurgical Co.)*.—This plant came into first production in April, and the contractor estimates it will be in full production by year's end. Analysis of the first production, which has been sold to others, was satisfactory.

7. *DMP–6, E. I. du Pont de Nemours & Co.*—As has been reported, the advance for the construction of the plant has been repaid and practically no problems remain with respect to this contract. Du Pont has announced, as is generally well known, that it is expanding its facility by 100 percent or to a 7,200 annual capacity. Late reports of production bear out this progressive expansion undertaking.

8. *GS–OOP (D)–12047, Titanium Metals Corporation of America.*—As is the case with Du Point, TMCA has announced an unassisted expansion of a substantial percentage, from 3,600 tons per year to 6,000 tons per year. Late report of production show that this expansion is under way. We have not received any sponge from this company for sometime as the latest poundage payment was made in cash. As is known from prior reports the revolving fund contracts with Du Pont and TMCA, under which GSA took excess production over a period of many months in order to prevent plant closings, expired September 30, 1955, and following the directive of ODM to curtail Government sponge purchases to the greatest extent practicable, were not renewed. This has posed no problem to either contractor in view of the increased demand for their products.

9. *DMP–116, Bureau of Mines.*—This is an experimental contract under which the Bureau is developing data as to the feasibility of producing slag from domestic ilmenites, and chlorinating such slag to produce titanium tetrachloride. Reports of progress show that the work is proceeding slightly ahead of schedule. It is too early to venture an opinion as to the results to be accomplished.

PILOT PLANT PROPOSALS UNDER CONSIDERATION AWAITING ODM AND/OR MAB APPROVAL

1. *National Research Corp.*—This company submitted a proposal to construct and operate a pilot plant for the melting of titanium scrap in a radiation-cooled skull type melting furnace. The cost is approximately $500,000. The proposal has been approved by the MAB and is being prepared for ODM approval.

2. *Metal Hydrides, Inc.*—This company submitted a proposal to construct and operate a pilot plant for the recovery of titanium scrap through the electro-refining process. The proposed cost is $730,255.

The company has been requested to submit additional technical and cost data, which is being awaited.

SUMMARY

Under the ODM policy directive of September 1955, GSA is not entertaining any applications for expanded capacity but continues to develop and entertain proposals looking to the piloting of new processes or substantial variations of the Kroll process designed to lessen production costs and improve metal quality.

As of June 30, 1956, the total D inventory of titanium sponge, from all sources, was approximately 7,800 tons, of which approximately 2,250 tons are plus 140 Bhn. Efforts are underway to dispose of the plus 140 Bhn sponge, probably by exchange, in order that the inventory will ultimately conform to the hardness limitation now contemplated with respect to a stockpile.

MISCELLANEOUS

Titanium sponge production for the year 1955 from plants within the cognizance of this office was as follows:

	Tons
Du Pont	3,091
TMCA	3,680
Cramet	517
Dow	73
Total	7,361

It has been generally reported that approximately 500 tons of Japanese-produced sponge were bought and used by domestic industry during the year although this office does not maintain figures on the subject.

Sources of Titanium Ores

With the rapidly increasing importance of titanium in our metals economy it is of importance to those interested in the metal to know something about the sources of the raw materials from which it can be made. In response to a request from Chairman Murray, the United States Bureau of Mines has compiled the following information:

> The mineral generally used for making titanium sponge is rutile, although one major producer in this country uses a mixed product containing altered ilmenite and rutile, and some Japanese producers reportedly use slag from ilmenite-bearing iron sands. In general, the titanium minerals that might be considered suitable for production of titanium metal are rutile, ilmenite, and their alteration products. Rutile, an oxide of titanium, consisting theoretically of 100 percent

TiO_2 (titanium dioxide), can be obtained in commercial concentrates that analyze more than 92 percent TiO_2. Ilmenite, an oxide of ferrous iron and titanium, theoretically contains 52.7 percent TiO_2 and 47.3 percent FeO. However, in altered ilmenite some of the iron is replaced by titanium, thus raising the titanium content above the theoretical amount. Where ilmenite occurs in individual grains it can be obtained in commercial concentrates analyzing 45 to 63 percent TiO_2, the higher grade concentrates commonly containing some altered material. Ilmenite also occurs intimately combined with other minerals, principally magnetite or hematite (two oxides of iron), making it difficult to separate the ilmenite in high-grade concentrates. Because the best obtainable concentrates from these deposits having intergrown ilmenite usually contain less than 35 percent TiO_2, they are not commercially attractive, and hence the deposits are not now utilized.

Rutile is the preferred ore for sponge production because of its high titanium content, its lack of iron, and the fact that it can be chlorinated directly to make titanium tetrachloride, one of the principal ingredients for making titanium sponge. Ilmenite generally is not used for making sponge, but is the principal raw material used in the manufacture of pigments. Ilmenite is not preferred for making sponge because its high iron content makes direct chlorination difficult and results in a high consumption of chlorine. Consequently, in order that ilmenite be used for making titanium metal, it is desirable that it be converted to a product, such as titania pigment or high-titania slag, that can be chlorinated directly. At present, experiments are in progress to find an economic method of converting domestic ilmenite to products suitable for chlorrination. Such investigations are deemed necessary, because in time of emergency or greatly increased demand, it would be difficult to obtain sufficient supplies of rutile, inasmuch as a large part of that required for domestic consumption must be imported.

Deposits containing ilmenite intimately associated with other minerals are not generally exploitable under present economic conditions, because high-grade ilmenite concentrates cannot be obtained. Exceptions are a deposit at Allard Lake, Canada, and sand deposits in Japan, ores from which are smelted to yield pig iron and a slag of high titanium content. The utilization of most of these low-grade ilmenite deposits will require further technologic research aimed at producing high-grade titaniferous products.

The accompanying tables show domestic and foreign resources of deposits that can be utilized for metal production under present economic conditions. Also included is resource information on deposits representing possible future sources for metal production, provided that economic and technologic problems can be worked out. The resource information presented herein has been compiled from data available in various published sources. Many of the figures represent estimates, as detailed work is lacking for numerous deposits.

Domestic deposits that can be used for metal production under present economic conditions are shown in table 1. These rutile-bearing deposits total 114,600,000 tons of titaniferous material containing 545,000 tons of TiO_2. The largest deposits occur in Florida, where sands are mined for rutile and other minerals. Rutile is also mined from a small deposit in South Carolina.

Foreign deposits that can be utilized for metal production under present economic conditions are shown in table 2. These deposits, all containing rutile, total 121,900,000 tons of material containing 9,266,000 tons of TiO_2. Australia is the principal source of rutile in the free world, and supplies approximately two-thirds of our domestic requirements. The importance of Australia's position can be shown by the fact that between 1950 and 1954, the other foreign rutile-producing countries, Brazil, French Cameroons, French Equatorial Africa, India, Norway, and Senegal produced only 1,366 tons of rutile, whereas in the same period, Australia produced 193,417 tons of concentrates, and the United States 36,085 tons.

Domestic deposits of potential importance in the near future, but not used for metal production at present are shown in table 3. Resources of these deposits are 480,879,000 tons of titaniferous material containing 26,663,900 tons of TiO_2. Included in this category are: (1) deposits of rutile that cannot be mined under present economic conditions; (2) deposits of ilmenite that are being mined, primarily to supply ore for pigment plants; and (3) deposits of ilmenite that could yield marketable ilmenite concentrates, but for economic reasons are not operating at present. Although all of these deposits are not now economic sources for metal production, they could be used in the event of an emergency. Furthermore, changing economic conditions, particularly in the price of rutile, could make some of the deposits competitive with presently operating domestic and foreign deposits of rutile. The Arkansas and Virginia rutile deposits shown in table 3 were formerly mined. However, they are not operating today because they are of low grade and are not competitive with other supplies of rutile. Although minor amounts of rutile occur in many placer deposits, the domestic rutile deposits shown in the tables comprise the known deposits in which rutile is the major commercial mineral. Currently, a program is contemplated by the Department of the Interior to study titaniferous deposits in order to obtain more complete information on resources and usability. When this information is made available to industry, it should encourage greater investment and increased production.

Domestic deposits that cannot be exploited under present conditions are shown in table 4, and total 149,300,000 tons of titaniferous material containing 23,009,000 tons of TiO_2. Because most of these deposits contain ilmenite that cannot be recovered by any economic process at present, utilization

must await further technologic development or vastly different economic conditions.

Foreign deposits of potential importance in the near future, but not utilized for metal production at present, are shown in table 5. These total 498,632,000 tons of titaniferous material containing 123,829,000 tons of TiO_2. Most of these deposits at present provide ores for the pigment and ferroalloy industries, and probably could be used for metal production in times of need. Foreign deposits that are not exploited are shown in table 6, and total 663,488,000 tons of titaniferous material containing 60,351,000 tons of TiO_2. These, like the nonexploited domestic deposits, will probably not be used in the near future.

TABLE 1.—*Domestic deposits that can be utilized for metal production under present economic conditions*

State	Tons of titaniferous material	Grade (percent TiO_2)	Tons of contained TiO_2	Type of deposit	Remarks
Florida	[1] 114,600,000	0.48	545,000	Sands	Important producer of rutile concentrates.
South Carolina	[2]	[2]	[2]	Stream sands and gravels	Production of rutile concentrates from 1 deposit.
Total	114,600,000		545,000		

[1] Mixed product is also mined and utilized for metal production by 1 producer, but reserve figures are not available for this deposit.

[2] No reserve information.

TABLE 2.—*Foreign deposits that can be utilized for metal production under present economic conditions*

Country	Tons of titaniferous material	Grade (percent TiO_2)	Tons of contained TiO_2	Type of deposit	Remarks[1]
Australia	14,400,000	17.7	2,554,000	Beach sands	Major producer. Produced 193,417 tons of concentrates from 1950 to 1954.
Brazil	[2]	1.0		Rutile in pegmatites	Produced 25 tons of concentrates from 1950 to 1954.
French Cameroons	[2]	.2		Residual sands and gravels	Produced 708 tons of concentrates from 1950 to 1954 mainly for use in ceramics.
French Equatoral Africa	[2]			Stream sands and gravels	Produced 7 tons of concentrates from 1950 to 1954.
India	80,000,000	2.4	1,900,000	Beach sands	Deposits in Travancore State. Deposits mined for ilmenite and most of rutile discarded. Produced 490 tons of concentrates from 1950 to 1954.
Mexico	27,500,000	17.5	4,812,000	Rutile in anorthosite	Not in production. Reserve estimates from published company figures.
Norway	[2]	7.5		Rutile in fine-grained dikes	Produced 104 tons of concentrates from 1950 to 1954.
Senegal	[2]	25.0		Beach sands	Produced 32 tons of concentrates from 1950 to 1954.
Total	121,900,000		9,266,000		

[1] All production is rutile concentrates.

[2] No information.

TABLE 3.—*Domestic deposits of potential importance but are not utilized for metal production under present economic conditions*

State	Tons of titaniferous material	Grade (percent TiO_2)	Tons of contained TiO_2	Titaniferous mineral	Type of deposit	Remarks
	Deposits of rutile not commercially mineable at present					
Arkansas	12,500,000	3.1	387,500	Rutile	Rutile-bearing feldspar and carbonate veins.	No production at present. Produced at Magnet Cove until 1944. Does not economically yield rutile concentrates.
Virginia	5,330,000	3.0	155,000	do	Rutile in anorthosite	No production at present. Production at Roseland from 1903 until 1949.
Total	17,830,000		542,500			
	Deposits of ilmenite presently being mined					
Florida	66,700,000	0.84	560,000	Altered ilmenite	Sands	2d most important producer of ilmenite for manufacture of pigments.
Idaho	[1] 262,500,000	.14	360,000	Ilmenite	Stream sands and gravels	Ilmenite recovered as byproduct of monazite mining.
New York	100,000,000	20.0	20,000,000	Ilmenite	Ilmenite and magnetite in anorthosite.	Most important producer of ilmenite for manufacture of pigments.
Virginia	26,000,000	19.2	5,000,000	do	Ilmenite in nelsonite	Figures are reserves of 1 operator. National Lead Piney River deposit. Producer of ilmenite concentrates for manufacture of pigments.
Total	455,200,000		25,920,000			
	Deposits of ilmenite not being mined at present					
North Carolina	[2] 229,000	16.8	38,400	Ilmenite	Stream sands and gravels	3 small deposits. No production at present. An ilmenite mine in schist operated until 1952.
Oklahoma	7,620,000	2.1	163,000	do	Stream sands	No production. Preliminary tests indicate that concentrates contain 44.1 percent TiO_2.
Total	7,849,000		201,400			
Total of all deposits	480,879,000		26,663,900			

[1] Estimates for Valley County only.
[2] Total weight of heavy minerals, of which 65,700 tons are ilmenite.

TABLE 4.—*Domestic deposits that are not exploitable under present economic conditions*

State	Tons of titaniferous material	Grade (percent TiO_2)	Tons of contained TiO_2	Type of deposit	Remarks
California	6,000,000	17.5	1,050,000	Intergrown ilmenite and magnetite in anorthosite.	Area was investigated by a large company, but no development work undertaken.
Idaho			150,000	Ilmenite in high-alumina clay	Ilmenite available only as a byproduct if clay is mined for its aluminum.
Minnesota	94,600,000	15.2	14,400,000	Intergrown ilmenite and magnetite in gabbro.	
Montana	4,500,000	6.0	270,000	Intergrown ilmenite and magnetite in sandstone.	
New York	21,500,000	18.4	3,960,000	Intergrown ilmenite and magnetite in gabbro and anorthosite.	
Oregon	6,550,000	5.0	325,000	Ilmenite in ferruginous bauxite	Ilmenite available only as a byproduct if bauxite is mined for its aluminum.
Rhode Island	7,000,000	9.8	686,000	Intergrown ilmenite and magnetite in gabbro.	
Washington			890,000	Ilmenite in high-alumina clay	Ilmenite available only as byproduct if clay is mined for its aluminum.
Wyoming	9,150,000	14.0	1,278,000	Intergrown ilmenite and magnetite in anorthosite.	Estimates by the Union Pacific RR. in 1953, indicate 178 million tons of material containing 1.78 million tons of TiO_2.
Total	149,300,000		23,009,000		

NOTE.—Large tonnages of ilmenite are contained in waste material discarded by plants treating Arkansas bauxite to produce alumina.

TABLE 5.—*Foreign deposits of potential importance, but are not utilized for metal production under present economic conditions*

Country	Tons of titaniferous material	Grade (percent TiO_2)	Tons of contained TiO_2	Type of deposit	Remarks
Australia	14,400,000	15.3	2,204,000	Ilmenite in beach sands	Ilmenite is a byproduct of rutile industry. Cannot be used for pigments because of high chromium content.
Canada	151,300,000	35.0	52,981,000	Ilmenite in anorthosite	Deposit at St. Urbain yields ilmenite concentrates. Ore from deposit at Allard Lake is smelted to yield a slag containing 70 percent TiO_2. Sorrell.
Egypt	15,000,000	25.7	3,855,000	Ilmenite in sands of Nile Delta	In production.
Finland	50,000,000	13.5	6,750,000	Ilmenite and magnetite in amphibolite	Deposit at Otanmäki. In production.
India	80,000,000	37.5	30,000,000	Altered ilmenite in beach sands	Deposits in Travancore State. Most important prewar producer, and still supplies a large tonnage of concentrates.
Japan	41,632,000	8.5	3,539,000	Ilmenite in iron-bearing beach and terrace sands.	Ore is smelted to yield a high-titania slag.
Norway	146,300,000	16.7	24,500,000	Ilmenite in anorthosite	Important producer of ilmenite for pigment industry.
Total	498,632,000		123,829,000		

TABLE 6.—*Foreign deposits that are not exploitable under present economic conditions*

Country	Tons of titaniferous material	Grade (percent TiO_2)	Tons of contained TiO_2	Type of deposit	Remarks
Canada	6,310,000	19.5	1,228,000	Ilmenite and magnetite in anorthosite	Numerous deposits in Quebec. Will not economically yield concentrates.
Ceylon	[1] 6,400,000	43.7	2,800,000	Beach sands	
Formosa	243,000	11.0	27,000	Sands	
India	51,143,000	12.0	6,136,000	Various deposits in rock	No large, economically minable deposit.
Korea	2,535,000	20.0	507,000	Ilmenite and magnetite in gabbro	
Madagascar	3,887,000	26.9	1,045,000	Various deposits in rock	
New Zealand	50,000,000	9.0	4,500,000	Beach sands	Will not economically yield ilmenite concentrates.
Norway	19,525,000	5.8	1,141,000	Various deposits associated with anorthosite and gabbro.	None will economically yield ilmenite concentrates.
Sweden	248,017,000	6.7	16,700,000	do	Do.
Union of South Africa	25,428,000	5.0	1,267,000	Mostly beach sand deposits in Natal	Beach deposits were developed in 1954, but no production reported.
U. S. S. R	250,000,000	10.0	25,000,000	Various deposits, mostly in Ural Mountains.	May be exploited, but no information available.
Total	663,488,000		60,351,000		

[1] Total weight of heavy minerals.

NOTE.—Tanganyika Rapid reconnaissance survey of a large deposit at Liganga showed 1.3 billion tons of ore containing 171 million tons of TiO_2; this estimate possibly is high.

Union of South Africa mineralized material in anorthosite and gabbro of Bushveld complex reportedly totals 2.4 billion tons, containing 400 million tons of TiO^2; not economic.

The subcommittee staff report of August 19, 1955, stated various conclusions which, in the light of the months that have passed, and considering how rapidly the position of titanium among the light metals has advanced, should be reevaluated. The report stated:

TECHNOLOGY ADVANCING RAPIDLY

1. The subcommittee staff is firmly of the opinion that no metal ever has made such rapid progress in winning a place for itself as has titanium; and its utilization today is, though progressing satisfactorily, in its infancy. Aluminum, magnesium, and the alloy steels went through the same difficulties but the problems were solved gradually and over a period of many years. Alloy steels still present problems. There is complete justification for great optimism about the future of titanium as the evidence shows that its technology is advancing by leaps and bounds and the most knotty problems are being satisfactorily solved almost daily.

The subcommittee staff sees no reason for changing its position on the above conclusion.

The Battelle Memorial Institute, in summarizing recent technological advances, reported as of October 19, 1956, as follows:

TITANIUM FABRICATION PROGRESS

INTRODUCTION

Titanium production has steadily increased at about the expected rate for the past year. Mill-product production is now approaching a rate of 500 tons per month and will total almost 5,000 tons for 1956. This increase, from 1,300 tons in 1954 and 1,900 tons in 1955, is due primarily to three developments in titanium application: (1) The introduction of titanium forgings and extrusions into a production aircraft gas-turbine engine, (2) increased production of the high-performance military aircraft using titanium that were already in production a year ago, and (3) the start of production during the past year of other high-performance military aircraft designed to use significant quantities of titanium. These three application developments are a result of progress made in improving the uniformity of mill products and in solving fabrication problems that were unsolved a year ago, and the considerable refinement of metal-processing techniques for titanium alloys that has been possible as production applications have increased; progress primarily in melting, rolling, sheet forming, and forging.

The price of titanium sponge today is 25 percent less than a year ago. Mill-product prices have declined by more than the decrease in sponge cost, but not by as high a percentage.

Titanium usage in aircraft should increase significantly as the required research is accomplished to permit four main developments: (1) The development of uniformly heat treatable titanium alloy sheet, (2) the development of titanium honeycomb sandwich panels and construction techniques, (3)

the development of techniques to reproducibly heat-treat forgings and other massive titanium parts, and (4) the commercial availability of extrusions for airframe use. Assuming these developments; assuming further substantial reduction in mill-product prices; and assuming continued large-scale Government support; titanium production should continue to rise, on the basis of use of titanium in aircraft alone. Extensive nonaircraft applications still await a drastic reduction in titanium mill-product prices and the appearance of commercial titanium castings.

MELTING

Consumable electrodes have replaced inert electrodes in commercial melting practice, resulting in the elimination of contamination of the melt by the electrode and in the production of larger ingots. Reduced-pressure melting to decrease contamination, especially by hydrogen, and double melting to improve chemical homogeneity, have been generally adopted for commercial practice. Skull melting, while further along than a year ago, is still in the development stage. Most details of the developments and refinements of melting techniques are considered confidential information by the titanium melters. Achievements in this field can be substantiated largely in terms of increased production and improved quality of mill products. The past year in titanium has been notable on both of these counts.

Melting capacity has approximately doubled during the last year. Plans announced in the press indicate that melting capacity will probably again double during the next 12 months to reach 25,000 to 30,000 tons annually by 1958. With a product yield of about 50 percent of the ingot, it will be necessary that the ingot-melting capacity be about double the mill-product requirements.

ROLLING

Progress in titanium-rolling practice has occurred simultaneously with improvements in melting. This progress is reflected in continued improvements in quality and uniformity of titanium mill products and in increased production rates.

Over the past 12 months, monthly production of sheet materials has increased from an average of about 150,000 pounds to almost 300,000 pounds. Improvements in flatness, freedom from surface scratches, and gage tolerance have been more notable for commercially pure titanium than for the titanium alloys. These advances have resulted in part from the development of continuous rolling techniques for the unalloyed material. One titanium user, who has used about 15 percent of all commercially pure sheet sold to date, recently reported a steady and progressive improvement in uniformity of as-received properties over the past several years. These statistics indicate that only half as much mate-

rial that is outside the specified property ranges reaches this user's plant today as was the case a year ago.

Similarly, the surface quality and consistency of mechanical properties of sheet of the Ti–8Mn, Ti–5Al–2.5Sn, Ti–6Al–4V, Ti–2Fe–2Cr–2Mo, and other alloys have also improved over the past year, although flatness and gage tolerance for the alloys are both inferior to commercially pure sheet and short of the standards that the aircraft industry has set for aluminum-base sheet alloys—by considerable margins in the case of the titanium alloys which contain aluminum. Generally, the producers are making wider sheets and thinner gages than were available in early 1955. Commercially pure material is available in thinner gages than alloys, and in sizes larger than the standard 36 by 96 inches; the aluminum containing alloys are sometimes available only in subsize sheets.

A little over a year ago, the embrittlement of titanium-alloy sheet as a result of contamination by small amounts of hydrogen was a problem. Since then, the hydrogen content of commercial titanium sheet mill products, as received by the user, has been significantly lowered, although it remains a matter of concern. An Air Force survey reported that in the summer of 1954 about 50 percent of titanium sheets surveyed contained more than 150 parts per million of hydrogen, the current Air Force specified maximum hydrogen content for titanium sheet material. In the fall of 1955, according to an exhaustive survey of the Titanium Metallurgical Laboratory, samples from about 15 percent of alloy sheet shipped during a 3-month period was above the Air Force hydrogen maximum of 150 parts per million. More recent data from one user of large amounts of titanium-alloy sheet show that his rejection of sheet for excessive hydrogen content now is in the 5- to 10-percent range. This user's sheet rejection rate for all causes is in the 10- to 15-percent range. The progress in reducing hydrogen content has been made concurrently with research which demonstrates the problems associated with excessive hydrogen content in certain titanium-sheet materials.

The DOD sheet-rolling program, planned and implemented in the past 15 months by the three military services and the Office of the Secretary of Defense, has as one of its prime objectives assistance to producers to develop optimum rolling techniques for several of the most promising new, heat treatable, high-strength alloys. The materials selected for this program include the Ti–6Al–4V, Ti–2.5Al–16V, Ti–4.5Al–3Mo–1V, and the Ti–3Al–6Mo alloys. The sheet-rolling program is being coordinated by the Bureau of Aeronautics for the Department of Defense steering group on titanium research and development, with a panel of the Materials Advisory Board of the National Academy of Sciences providing program guidance. Appropriate contracts were negotiated in April 1956, calling for the production, under the sheet-rolling program, of about 90,000 pounds of alloy sheets. Several other similar programs involving high-strength sheet alloys have been negotiated within the past year by the United

States Air Force to expedite the accumulation of production experience, as well as to collect mechanical property data and to gain experience with fabrication techniques.

The titanium producers still operate under a handicap so far as fabrication equipment in general and rolling mills in particular are concerned. Much of the equipment being used at present was designed primarily for steel. With the exception of extrusions, titanium generallly requires about a 30-percent higher energy to hot work than does steel. The Ti–6A1–4V and Ti–5A1–2.5Sn alloys, due to their relatively high aluminum contents, which impart high-temperature strength, are especially difficult to fabricate. At the present time all of the producers are installing equipment to improve existing facilities. Important is the trend toward using electrically heated furnaces, the planned erection of rolling mills designed specifically for titanium rolling, and the installation of vacuum heat-treating furnaces to handle larger sheet sizes in greater quantities than presently possible. As more of these new facilities are put into production, the quality of titanium-sheet materials will continue to improve.

SHEET FORMING

Progress in the forming of titanium sheet into airframe and jet engine parts over the past year or so has paralleled and reflected the improvements in uniformity and quality of sheet material. The increase in sheet usage from about 150,000 pounds per month a year ago to about 300,000 pounds per month today is an indication of sheet-forming progress. One of the major users of titanium sheet in airframes has mentioned that plant rejection rates on formed sheet details have been reduced to one-quarter of those experienced in 1955. This improvement is attributed to more rigid receiving inspection, to improved tooling and heating techniques, to revised forming limits, and to generally increased know-how; as well as to the improvement in quality of sheet being shipped by the producers. In spite of this progress, it must be noted that sheet-metal scrap losses for 1956 may still approach 10 percent of total sheet production and may involve a dollar loss of several millions of dollars. It is also noteworthy that small-scale titanium users are relatively less convinced of improvements in sheet quality than large-scale users; presumably owing to their unfamiliarity with the material compared to the more experienced users.

A new sheet alloy, Ti–2Fe–2Cr–2Mo, was introduced into the production of aircraft during the past year. This alloy, now being used in amounts up to 15 percent of total sheet usage by one large-scale user of titanium sheet, has shown, both in evaluation and in practice, such good sheet forming properties as to result in what is reported as markedly lower scrap and rejection rates.

Progress through refinement of sheet-forming techniques and accumulation of know-how is often difficult to document except as measured by reduced scrap rates and increased

production, both of which have already been noted. Basically, this progress is the accumulation of many small advances. One airframe company, for example, reported that it was able, after some experience, to reduce sheet-forming temperature by 200°, which in turn resulted in less difficult descaling operations. This advance, combined with improved descaling methods and already improved surface quality of incoming sheet, resulted in less difficult and more rapid sheet forming of titanium alloys in that plant.

HEAT TREATMENT

Within the past year titanium fasteners, heat treated for strength, have been introduced into some versions of one production military aircraft. Other than this, stress relieving is the only other heat treatment of titanium aircraft structural parts being done in production. In spite of this, progress in heat treating during the past year has been important. A year ago the technological basis for strengthening titanium alloys by heat treatment was well established in the laboratory and fairly well understood by titanium researchers, but few people in fabrication shops were aware of the potentialities of heat treating titanium. During the past year, however, most titanium users have devoted attention to heat treatment. Recently, one producer expressed willingness to sell titanium alloys with guaranteed heat-treated properties.

It is significant that at least 25 important reports and papers on heat treatment have appeared within the last year, and especially significant that 20 of these originated in laboratories of titanium users. The work represented by these reports, and additional work already accomplished but not yet reported, have developed enough data to permit designing of parts on the basis of heat-treated strength properties. It should be noted that alloys under development in the DOD sheet-rolling program were selected for their promise of heat-treated, production sheet material. Successful completion of this program should make these alloys available for use in production airframes.

WELDING

During the past year the inert gas shielded-arc welding of titanium on a production basis increased manyfold, mostly as the result of increased production of aircraft gas turbines using titanium. Of similar significance is the fabrication by spot welding of the all-titanium aft portion of the fuselage of one major aircraft model, which began on a production basis only about a year ago.

Specific achievements during the past year contributing directly to this progress were: (1) the development of procedures for edge preparation and joint fit-up which allow the control of weld-joint porosity, (2) the establishment of sufficient design engineering data and the completion of necessary prototype and laboratory tests, and (3) the adoption of

welding procedures and specifications that insure the production of strong ductile weld joints.

Another item of note is the interesting prototype application of flash welding to primary titanium alloy aircraft structure during the past year.

SANDWICH STRUCTURES

Concomitant with the successful production development of precipitation-hardenable stainless steel honeycomb sandwich panels during the past year has occurred the successful production of titanium honeycomb test panels in the laboratory. Titanium honeycomb sandwich is desired by airframe designers to save weight over either stainless steel honeycomb construction or conventionally built-up titanium structures in applications operating up to about 800° F. The development of titanium honeycomb is one of the most challenging problems faced by the engineers and scientists participating in titanium development. Honeycomb development depends on (1) the development of titanium alloy sheet in thin gages, which is heat treatable to tensile strengths of at least 160,000 pounds per square inch room temperature ultimate, and (2) establishing methods for joining together heat-treated titanium cover sheets and titanium or stainless steel honeycomb core.

SECONDARY FORGING

Progress in titanium alloy forging in the last year is evidenced by an increase in the requirements for forging and bar stock from about 150,000 pounds per month a year ago to over 500,000 pounds per month today. This increased requirement is due primarily to the introduction of titanium forgings into a production aircraft gas turbine.

One achievement that has contributed to progress in the use of titanium forgings is the development of techniques for precision forging titanium to heretofore unattainable tolerances. By improved techniques for protection against contamination through use of coatings, by good lubrication, and by well-developed hammer or rolling techniques, titanium jet engine compressor blades are being produced now within tolerances of 0.001 to 0.005 inch, and with greatly reduced flash compared with previously available products.

Perhaps 2 or 3 dozen small titanium forgings are now in use in production airframes. Extensive use of forgings in airframes awaits the development of high-strength, heat-treated forgings.

HOT EXTRUSIONS

An indication of progress in hot extrusions is the rate at which extrusions became available and were used in production during the last year. Compared with an almost complete absence of extrusions from the commercial market a little more than a year ago, at least 12 companies now extrude titanium either on an experimental, semicommercial, or com-

mercial basis. Nine accept orders on a limited guaranty or "best effort" basis. Three of the companies extrude airframe structural shapes, four are extruding or planning to extrude engine shapes, and six have extruded tubes. Finished engine parts are now being machined from titanium extrusions for one production engine model; no production usage existed a little more than a year ago.

Titanium extrusions have also been introduced into a production airframe within the past few months. These are 3- to 7-foot long extrusions of Ti–6Al–4V which are machined all over in producing the airframe parts. To be generally applied in airframes, extrusions should have surfaces smooth enough to be usable without machining. This surface finish requirement makes the production of titanium extrusions for airframes much more difficult than for engines. Extrusions of several alloys are being produced in lengths up to 15 feet for prototype evaluation (after machining all over) in airframes.

DRAWING OF TITANIUM TUBING AND WIRE

Techniques of drawing titanium and its alloys to wire are now fairly well established. Unalloyed grades are being commercially drawn to 0.030 inch and find their primary market in welding applications. The alloys Ti–6Al–4V and Ti–5Al–2.5Sn continue to prove difficult to draw to 30 mils, but some alloy wire is commercially available. As welding problems continue to be solved, the quality of welding wire still remains somewhat in doubt.

Production and fabrication of thin-wall tubing is receiving increased attention. Both drawn and welded tubing in a wide range of sizes and wall thicknesses are in commercial production, particularly in the unalloyed grades. About 15 organizations offer tubing for sale today as compared with only about 4 a year or so ago.

COATINGS

Although it has been reported during the past year that chromium can be adherently electroplated on titanium, no significant commercial application is as yet known. Likewise, the past year has seen experimental advances in solving sheet-forming lubrication problems through the use of chemical conversion coatings in conjunction with standard drawing lubricants. Anodic coatings have also been under investigation.

Several metallurgical coatings on titanium have been studied recently. Most interest has been on aluminum coating of titanium. An aluminum coating applied by either hot dipping or spray painting acts as a lubricant in hot-forming applications and also improves the resistance of titanium to oxidation in air at elevated temperatures. One engine manufacturer will soon use hot-dipped aluminum coatings in the preparation of much bar and forging stock. Two airframe

manufacturers have developed spray-painting techniques for titanium sheet materials. One uses the coating experimentally to protect sheet from air contamination during heat treatment and the other uses the coating primarily as a lubricant in forming operations.

As mentioned previously, the success achieved in precision forging over the past few months is reportedly associated with the use of a coating to protect against contamination during heating and striking.

CASTING

Titanium castings are not yet available on a commercial basis. During the past 12 months at least 10 organizations have undertaken work to develop furnaces, mold materials and alloys for titanium casting. For commercial reasons, little information on the progress of these programs is disseminated.

Titanium alloys cast to date have exhibited mechanical properties comparable with, but somewhat lower than, those for wrought alloys of the same composition. This relationship is normal for most engineering materials. To establish a titanium casting industry the development of an inexpensive mold material that does not contaminate titanium seems to be required.

POWDER METALLURGY

Although it has been demonstrated that titanium powder metallurgy products can have properties equivalent to wrought titanium, no manufacturing production by powder metallurgy techniques yet exists. This is probably due to the lack of any sizable market. In the past year or so, experimental programs have continued to produce dispersion hardened titanium powder metallurgy products and to make jet engine compressor blades by powder metallurgy techniques. Some prototype applications have been attempted; over 100 of each of 2 designs of valve trim made by powder metallurgy techniques have been installed for testing on naval vessels.

MACHINING AND GRINDING

Titanium is being machined satisfactorily today by those who are aware of difficulties involved and who know the proper techniques to apply to minimize them. With the exception of grinding, and considering current production rates, titanium is no longer considered a major machining problem in plants with titanium experience.

The fact that progress has been made does not mean that all machining problems have been solved. Considerable improvements of certain specific operations are needed; including blind-hole tapping, deep-hole drilling, drilling and tapping of holes less than one-eighth inch in diameter, and drilling titanium materials harder than about Rockwell

C–39. Also, to increase production capabilities and reduce capital equipment costs, developments to increase machining speeds are required.

INSPECTION AND CONTROL

Satisfactory methods are available for the chemical analysis of the alloying elements iron, chromium, molybdenum, tin, manganese, and nitrogen in titanium. Methods for determination of aluminum in titanium are considered to be too time consuming, although some simplification of the methods was achieved in the last year. The greatest present problem, so far as chemical analysis for alloying elements is concerned, is the lack of analytical standards.

Analysis for the gaseous impurities oxygen and hydrogen is more difficult than for the previously mentioned elements. During the past year almost all major users of titanium have installed equipment for hydrogen analysis and have learned to use it satisfactorily. This improved a previously difficult situation wherein hydrogen analyses could not be performed because of both a lack of facilities and a lack of analytical know-how. Recently gained experience and simplification of techniques has considerably reduced analytical costs. Reduction in costs for oxygen analyses should result from recently proposed, but not yet generally established, improved methods.

TITANIUM A "MUST"

2. Six out of eight aircraft manufacturing companies interviewed were convinced that the expanded use of titanium is a must if the United States is to maintain air supremacy. One company was somewhat less enthusiastic but still said it would have to use titanium. The eighth was ultraconservative, but apparently acts only under contract specifications set by one of the armed services. It is quite evident to the subcommittee staff that enthusiasm for the use of titanium is in direct proportion to the experience and the caliber of the research and the practical experience of each of the companies using the material.

The subcommittee staff feels that this conclusion not only is as valid as it was the day it was written but feels that its industry contacts indicate enthusiasm for titanium among manufacturers and fabricators is growing rapidly.

One large user in the aircraft industry informed the subcommittee:

> It is disturbing to hear the following argument:
> By using $15,000 worth of titanium we can reduce engine weight by 150 pounds, which will permit the airplane to carry 150 pounds more fuel. This is only enough fuel for about 1 minute at full power. On a round-trip basis it increases the effective range by only 30 seconds, or about 5 miles. The result is not worth the cost.

It is the type of argument that appears plausible at first sight, and so it could be dangerous in the hands of an unfriendly columnist or

politician who might use it to criticize the spending of big money for little gains. The argument ignores the fact that a lighter plane can fly higher, faster, and farther even without more fuel; or if more fuel is carried, the increased range will be in the cruise portion of the flight, at high altitudes, where fuel flow is only a small fraction of the full-power sea-level rate; most important, it ignores the "multiplication factor" in new designs, whereby each pound of engine or other saving in weight accounts for 8 or 10 pounds in the total airplane weight.

RESEARCH AND EXPERIENCE

Again the subcommittee staff wishes to repeat that enthusiasm for the use of titanium is in direct ratio to the experience, caliber of research, and practical experience of the companies using the material. The work of the Battelle Memorial Institute and the results from the Air Force, Army, Navy and other experimental contracts looms of greater and greater importance each day.

Industry and Government are spending many millions of dollars for the solution of numerous problems beginning with the reduction of the ores of titanium to metal and on through to design and final application.

In 14 broad areas of investigation, major effort is being devoted to processing, primary and secondary working, physical and metallurgical properties, and design and application.

There are now 12 companies of which 5 are in the United States, known to be commercially producing primary titanium metal. Ten companies, including four in the United States are using the Kroll process (magnesium reduction of $TiCl_4$) and the other two are using sodium reduction of $TiCl_4$. The Bureau of Mines is experimentally operating an electro-refining process pilot plant which is producing excellent quality metal from lower grade sponge or scrap. At least three private groups are known to be working on electrolytic processes. Small quantities of titanium are being made by the iodide process, and one company is seriously exploring this for commercial production. At least one group is reported to be working on a combined reduction and melting process which is aimed at producing ingots (rather than sponge) direct from purified titanium compounds. A small amount of metal is being produced for powder metallurgy by Metal Hydrides, Inc., by the reduction of TiO_2 with calcium hydride. There are numerous reports and rumors of varying degrees of reliability on other processes.

The general consensus of the industry is that the Kroll and/or sodium processes will be the primary means of making titanium for at least another 5 years, and new Kroll process capacity is still being installed. It is reported to be fairly easy to convert a Kroll plant to sodium reduction.

Technically, it appears that the odds are against putting the Kroll process on a continuous basis, but it appears that there is some likelihood that the sodium reduction process can be made continuous.

Under processing, the items that are receiving special attention are the recovery of $TiCl_4$ from ilmenite, development of a continuous sodium process, and further work on electrolytic processes. Work is currently going ahead on a fused salt process.

Much progress is being made in scrap recovery. Recovery of titanium scrap is inherently difficult both because the melting process does not refine the metal and because the usual arc melting process severely limits the form in which scrap may be handled.

In processing sponge to mill products about 25 to 35 percent of the original weight of sponge becomes scrap. In processing mill products to finished parts, up to 60 percent of the starting weight of mill products becomes scrap. In both cases, part of the scrap, estimated at 10 to 15 percent overall, is unrecoverable (pickling losses, grinding losses, etc.) Nevertheless, a large amount of potentially recoverable metallic scrap is being generated. Estimates vary between 50 and 90 percent as to the proportion of the scrap stockpile, which, after proper sorting, would be suitable for remelting, without refining, into ingots.

At present, the primary producers are still processing a certain portion of scrap into their ingots. Ingots meeting market specifications have been melted containing up to 100 percent scrap and 20 to 50 percent is more or less common.

Titanium powder metallurgy is still in an early stage of development. After a somewhat promising beginning, stimulated because of earlier difficulties in fabricating wrought titanium by conventional methods, the whole subject has recently received little emphasis. It would seem that as the use of titanium expands, the production by powder metallurgy methods of small components with high-temperature strength would be advantageous. By powder metallurgy methods, the need for remelting of metal is eliminated along with the elimination of high machining losses. Some alloys which are neither machinable nor formable may be handled by powder metallurgy techniques.

Powdered titanium presses and sinters rather easily in simple shapes, but the need for a high vacuum or very pure, inert atmosphere cannot be eliminated and constitutes a major problem. Poor sideways flow properties of titanium powder make the production of complex shapes a problem.

There is need for the development of high-temperature powder metallurgy alloys in alloy ranges not fabricable by usual techniques. Some effort could be devoted to development of an efficient extractive process in which the product is directly suitable for pressing and sintering, and to the use of titanium powder for protective coatings for other metals. Also, there appears to be a need for a current summation of all available technical data on powder metallurgy.

As almost all of the titanium produced today is used in military aircraft, it is clear that stimulation by the armed services, especially by allowing considerable additional sums of money per contract to pay the difference in cost between titanium and the usual materials of construction is of major importance. Although the subcommittee staff was assured by representatives of the Air Force that necessary extra funds would be liberally supplied where titanium could be substituted for other materials in planes now in production or designed into new planes, it has no specific information that such a policy vigorously is being carried out. The Assistant Secretary of Defense for Supply and Logistics has stated, however:

> In the preparation of the requirements calls that have been issued subsequent to May 1953, we have carefully placed no limitations upon the services or their contractors except that

the intended uses must be such that the military advantages would warrant the use of titanium rather than a cheaper alternate material.

It is especially interesting to note that considerable advance is being made in the use of titanium fasteners, which Major General Metzger felt is a prime field for quantity use in the near future.

KNOW-HOW SHOULD BE COMMON PROPERTY

3. It appears that the work the Battelle Memorial Institute is doing for the Government and industry in collecting and disseminating technical and scientific information on titanium is excellent, but the real bottleneck is the lack of means for communicating shop know-how. Each company seems to have solved certain practical problems on the shop level with which other companies still are wrestling. These are not solutions which readily can be communicated by the reading of technical papers, but have to be seen to be appreciated. General Metzger had hoped to generate intercompany visitation down to the level of the shop foreman into a general practice. The long-established habit of concealing as proprietary information certain shop know-how may further substantially retard the titanium program.

The subcommittee staff wishes to reemphasize its conclusion No. 3. Although, as previously remarked, there have been notable advances in disseminating know-how, many concerns, especially the smaller users, complain of having difficulty in learning how to work titanium. It is possible they are not aware of the help they can get by communicating with the Air Force, Battelle, or perhaps large companies which have had long experience with the metal. It is still felt that more effort should be made to interchange between users know-how on a shop level.

DEFENSE DEPARTMENT SHOULD LEAD THE WAY

4. The subcommittee staff feels there is an obvious lack of coordination and direction among the executive agencies and committees dealing with the titanium program. There is such a maze of redtape, routing, and timidity that an idea often becomes obsolete before it can be put into practice. Although the Department of Defense has the major interest in making titanium a success, it has not taken a strong enough lead in doing so. Efforts should be made to aid and assist in the procurement of specialized basic mill production equipment for titanium by the Department of Defense and/or its component agencies for materiel suppliers.

There is some reason to believe that there is a slight improvement in the agency situations commented upon in the above conclusion. However, little further investigation on these points has been carried out. When material is gathered for the next staff report it is expected that a complete study of this phase will be made.

Progress is being made by industry in ordering specialized equipment for working titanium but it appears there yet is a long way to go

before the situation is at all satisfactory. The effect of the steel strike (p. 63) indicates strongly how much special titanium facilities would help production. The Department of Defense should take a more leading part in this respect.

COST STUDIES ESSENTIAL

> 5. The subcommittee staff recommends that intensive study be given to lowering the cost of primary metal, and to the problem of scrap recovery, chemical machining, powder metallurgy, extrusions, integrated special facilities and greater opportunities for educating industry toward civilian uses.

This conclusion still is valid, although there has been, as noted elsewhere in this report, a lowering in cost of sponge, ingot, and mill products since the issuance of the first staff report. Air Force and other Government agency experimental contracts looking toward improving fabricating, machining, extrusion, and other techniques are showing concrete results. Scrap recovery still is not satisfactory and the solution of this problem will help to lower the price of end products. There have been several substantial moves toward plant integration for producing mill products which should help to improve quality and reduce price.

CURRENT REQUIREMENT FIGURES IMPERATIVE

> 6. Every effort should be made by the Government to collect current requirement figures with the least possible lag and to quickly formulate them into the program. Future projections of requirements appear to have been grossly underestimated and it is imperative that those responsible for making these estimates and transmitting them to the Office of Defense Mobilization take a new look at the picture and at the limitations now placed upon the sponge program.

The Office of Defense Mobilization has stated recently that it is making a resurvey of sponge requirements. In view of the enterprise of private industry in expanding sponge production facilities and reducing the price per pound of sponge, it seems unlikely that the Office of Defense Mobilization will take any further steps to encourage sponge production. The subcommittee has been informed as follows:

EXECUTIVE OFFICE OF THE PRESIDENT,
OFFICE OF DEFENSE MOBILIZATION,
OFFICE OF THE DIRECTOR,
Washington, D. C., August 27, 1956.

Hon. JAMES E. MURRAY,
Chairman, Committee on Interior and Insular Affairs,
United States Senate, Washington, D. C.

DEAR SENATOR MURRAY: This is in reply to your letter of August 14, 1956, indicating your desire to be informed of any change in the titanium sponge target of 22,500 tons.

A new set of data is now being developed for supply-demand study. I will inform you of the results of this study as soon as it is completed.

It might be of interest to note that recently Du Pont, and Titanium Metals Corp., announced plans for increasing sponge capacity with private funds. The action of these 2 producers would raise the sponge capacity figure to 31,500 tons.

Sincerely yours,

ARTHUR S. FLEMMING, *Director.*

As to collecting figures on requirements, there has been a definite improvement in techniques. The Honorable T. P. Pike, Assistant Secretary of Defense for Supply and Logistics, has informed the subcommittee that late in 1955 (subsequent to the publication of the first staff report on titanium), a procedure was established whereunder each 6 months the agency would receive a requirements forecast covering a constantly advancing 3-year period. The entire letter is quoted below:

ASSISTANT SECRETARY OF DEFENSE,
SUPPLY AND LOGISTICS,
Washington, D. C., April 20, 1956.

Hon. JAMES E. MURRAY,
United States Senate.

DEAR SENATOR MURRAY: Reference is made to your letter of April 5, to Mr. Carl Rolle requesting our comments on conclusion No. 6 of the staff report on titanium of the Special Subcommittee on Minerals, Materials, and Fuel Economics of the Committee on Interior and Insular Affairs.

This Office develops requirements for titanium mill products by issuing calls on the three military departments. The departments compute requirements generally by machine, using data as to the bill of materials for each end item, the production schedule for the item and the lead time between the need for the material and the final stage of end-item production and delivery. Data are consolidated by each department and reported to this Office. This Office reviews the data, examines the method and backup data as necessary, secures adjustments in the reported requirements where scrutiny so indicates, and finally consolidates the data into a single requirement for the Department of Defense.

In the instance of a new material such as titanium, the real problem in requirements estimating is to establish the probable unit content of titanium at a given future date; that is, to establish future "bills of material." Based on the best advice obtainable within the military departments and from contractors responsible for aircraft and engine design, the military departments generated a series of estimated requirements data for titanium mill products in 1952, in 1953, and in 1954. All of these were based on current, or nonmobilization, end-item production schedules and in each case the estimate was for a forward period of 3 to 5 years.

The requirements thus estimated for 1953, 1954, and 1955 were greater for each year than ultimate actual mill shipments during those years. This indicates the highly theoretical nature of those early estimates and the lack of knowledge of the practical problems that would be encountered and the time that would be needed to solve such problems.

By 1954 it had become evident that all estimates of requirements had been too optimistic, at least as to timing. The pendulum of engineering opinion swung the other way and for a time there was extreme pessimism in many quarters as to whether titanium ever would work out as a volume material of construction. In May 1955 we completed a new requirements estimate; this time covering the years 1955, 1956, and 1957. The estimate for 1955 was far lower than prior estimates for that year, reflecting the attitude at that time, and by the close of the year it was evident that it had been too low. The solution of major technical problems at last permitted substantial increased use and the shipments in 1955 exceeded the May estimate by 30 percent.

In view of the fact that actual titanium usage was at last growing to sizable proportions, the Department of Defense instituted in late 1955 a procedure whereunder each 6 months it would receive a requirements forecast covering a constantly advancing 3-year period. For your information we are enclosing a copy of Department of Defense Instruction No. 4210.9, revised November 9, 1955, which established this practice.

In the preparation of the requirements calls that have been issued subsequent to May 1953, we have carefully placed no limitations upon the services or their contractors except that the intended uses must be such that the military advantages would warrant the use of titanium rather than a cheaper alternate material.

Sincerely yours,

T. P. PIKE.

1 enclosure—DOD Instruction 4210.9 (revised November 9, 1955).

Number 4210.9
Date: October 24, 1955#

DEPARTMENT OF DEFENSE INSTRUCTION

Subject: Reporting of Titanium Requirements (DD–S&L. (SA)102R1).

Reference: DoD Directive 4210.9, Titanium Requirements, September 25, 1953.

I. PURPOSE

This Instruction sets forth procedures for the reporting of titanium requirements by the military departments for use of the Assistant Secretary of Defense (Supply and Logistics) in providing information in support of the titanium expansion program.

II. CANCELLATION

Referenced directive is hereby superseded and cancelled.

III. APPLICABILITY

The policies and procedures outlined in this Instruction are applicable to the Departments of the Army, Navy (including Coast Guard), and the Air Force.

IV. REQUIREMENTS REVIEW

Requirements will be reviewed for validity and accuracy at all appropriate levels in the military departments prior to their submission.

V. REPORT CONTROL SYMBOL

Report Control Symbol DD–S&L(SA)102R1 has been assigned to this report.
Report Control Symbol DD–S&L(Q)102 is cancelled.

VI. REPORTS REQUIRED

Semiannual reports reflecting three year requirements for titanium are to be submitted in accordance with detailed instructions contained in Enclosure 1 to this Instruction.

VII. EFFECTIVE DATE

This Instruction becomes effective on the date of issuance.

T. P. PIKE,
Assistant Secretary of Defense
(Supply and Logistics).

Enclosures—3.
(1) Instructions for Preparation of Semi-Annual Reports.
(2) Instructions for Submission of DD Form 683.
(3) DD Form 683.
#Revised November 9, 1955.

4210.9 (Encl 1)
Oct. 24, 55

INSTRUCTIONS FOR THE PREPARATION AND SUBMISSION OF RECURRING FORECASTS OF CURRENT REQUIREMENTS FOR TITANIUM AND TITANIUM BASE ALLOYS

1. Data required

The Departments of the Army, Navy, and Air Force will submit three-year forecasts of current program requirements for each of the forms and shapes of titanium and titanium base alloys listed in paragraph 2 below. Data will be submitted in duplicate by procurement (claimant) program (DoD Directive 4000.7, 8/21/52).

2. Mill products to be reported

a. Requirements will include titanium and titanium base alloys for "A" Products and metal purchased as such. Titanium content as a stabilizer in ferrous alloys is not to be reported. Shapes and forms are prescribed in the Department of Defense Coded List of Materials dated September 1953 (DoD Directive 4210.1, 9/24/53), and are to be reported as follows:

0700	Titanium and Titanium Base Alloys	Pounds
0710	Castings, Total	Pounds
0720	Raw Stock Forms Total (except sponge) 0721, 0722, 0724, 0725	Pounds

0721	Casting Stock	
0722	Forging Stock	
0724	Ingots, Billets, Blooms, and other raw stock forms excluding casting and forging stock	Pounds
0725	Powder (exclude Titanium Oxide)	
0730	Plate, Sheet and Strip Products, Total	Pounds
0740	Rod and Bar Products, Total	Pounds
0750	Shapes, Rolled or Extruded, Total	Pounds
0760	Pipe and Tubing, Total	Pounds
0770	Wire and Wire Products, Total	Pounds

NOTE.—For materials reporting purposes, *forgings* are to be included in terms of the form or shape in which the semifinished metal (such as ingots, billets, blooms, bars) for making the forgings is procured.

b. Titanium shapes and forms are the various mill forms of commercial titanium and titanium base alloys which, in general, can be defined as containing 85% or more of titanium. The titanium content of other ferrous and non-ferrous alloys is not to be reported.

3. Requirements forecast coverage

a. Each forecast will cover a period of three years. The first year will be phased by quarters, the second year by half years, and the third year as a single total. The following schedule of submission due dates and periods covered by each semiannual submission will apply.

Due Date of Submission to OASD(S&L)	Period of Mill Product Delivery to be Covered	
	From—	To—
1 Feb 1956	1 Jan 1956	31 Dec 1958.
1 Oct 1956	1 Jul 1956	30 Jun 1959.
1 Apr 1957	1 Jan 1957	31 Dec 1959.
1 Oct 1957	1 Jul 1957	30 Jun 1960.
Each 6 months thereafter	Each 6 months thereafter	Each 6 months thereafter.

b. In order to account for the materials lead time, production schedules and programs used as the basis for requirements will be estimated as necessary, beyond the period covered by current financing.

c. If a significant change in requirements takes place during any particular period between reporting dates, such information is to be reported to the Assistant Secretary of Defense (Supply & Logistics) immediately.

4. Base for developing requirements

a. Basic assumptions

(1) The supply of titanium (sponge and mill products) will be increased rapidly enough to meet requirements; hence, concern over the availability of adequate quantities will not influence a forecast of proposed additional use.

(2) Titanium and titanium base alloys will be freely utilized in those applications in which they will improve performance of equipment with a resultant military advantage commensurate with additional cost. Titanium will not be used in lieu of more economical materials where equal performance characteristics will result. Exceptions to this will be developmental projects, manufacturing methods projects,

and production applications aimed principally at gaining engineering and manufacturing methods experience.

(3) The timing of adoption of proposed new uses on a production scale will be estimated on the basis of the best-considered evaluation of the known and anticipated problems (such as alloy development, material uniformity and quality, fabricating technique, etc.) involved and of the time likely to be required to solve such problems. Where a substantial question exists on the part of the manufacturer or the Department concerned as to the probable timing of a new application, the timing adopted for the purpose of this report may be footnoted as to the range of variation.

(4) Requirements will be based on scheduled production of equipment to the fullest possible extent. For the purpose of covering materials lead time beyond current buying programs and budget estimates, future annual budgets will be assumed equal to the latest one in effect at the time of reporting.

b. Production Schedules

The schedules used in the determination of the requirements, where detailed computations are specified, will be consistent with those contained on the latest approved DD Form 750 prepared in accordance with DOD Directive 4200.5 dated March 4, 1954 (Report Control Symbol DD–S&L (SA)–137R1) or equivalent schedule, or in equipment and supply reports available at the time of reporting. Consideration should be given to the extent to which current delivery forecasts modify such schedules. Information identifying the schedules will be submitted with the requirements. In addition, a list of the items and components using titanium which are included in the requirements will be submitted with the report.

c. Unit Weight and Lead Times

The unit weights and lead times used, where detailed computations are specified, will be submitted with the requirements. In addition, the source of the unit weights will be identified, e. g., Bills of Material, APRA–5, Engineering Estimates, DD Forms 683, etc.

d. DD Form 683

DD Form 683 will be utilized if contractor data are required by the reporting departments. The "Instructions for Submission of DD Form 683" (Enclosure 2) and Form DD 683 (Enclosure 3) have Bureau of Budget approval.

5. Materials requirements responsibilities under single service procurement

The service procuring items for another service will be responsible for computing the material in the "A" product portion of such items. The using service is responsible for furnishing the purchasing service with firm requirements for "A" products to be purchased in its behalf as far in advance of the reporting date as required by the purchasing service. The purchasing service is not responsible for reporting re-

quirements which are not received in time to be included in the computation.

6. Reporting format

Data submitted to the Office of the Assistant Secretary of Defense (Supply and Logistics) in accordance with these requirements must be arranged as follows:

Column 1: DD Materials Classification Code.

Column 2: Mill Products Products (as shown in paragraph 2, page 1 of the detailed instructions).

Columns 3–6: First year requirements phased by quarters.

Columns 7–8: Second year requirements phased by half years.

Column 9: Third year requirements, total only.

The format should not exceed 16 by 10½ inches in size and should identify the report as "forecast of Current Requirements for Titanium and Titanium Base Alloys." A separate format should be used for reporting requirements under each "Procurement Program."

7. Security classification

Data submitted under this Instruction will be classified CONFIDENTIAL unless higher classification is required.

8. Substantiation and review

Included with the submission of requirements, the department will indicate the schedules used as a basis of computation and will furnish estimated unit weights for major consuming items. In the event that a method other than the schedule-unit weight is used for the estimate, an explanation of the method used will accompany the requirements; e. g., dollar factors, percentage of total weight, etc. Requirements will be reviewed for validity and accuracy at all appropriate levels in the military departments prior to their submission.

9. Class A and class B products

Material requirements for Class B Products will not be included except for those B Products which by directive can be included (see P. A. M. Sec. 3, Part 2.1). Definitive list of Class B Products is contained in the latest "Official B Product List."

4210.9 (Encl 2)
Nov 9, 55

INSTRUCTION FOR THE SUBMISSION OF DD FORM 683—TITANIUM REQUIREMENTS FORECAST (TITANIUM AND TITANIUM-BASE ALLOYS)

A. General Instructions

1. DD Form 683 will be prepared by the contractor and will cover a period of three years. For the first year of the reporting period indicate separately the total quantity per quarter. For the second year by half years, and total for third year.

2. Quantities shown as "Total Per Quarter," "Total Per Half Year," or "Total for Year" should be those amounts of materials for which delivery is required during the specified period reported.

3. All titanium and titanium-base alloys used by the prime contractor and his subcontractors should be listed except that material for the manufacture of CMP "Class B" purchased products will be excluded.

4. Titanium and titanium-base alloys, for the purpose of DD Form 683, are the various mill forms of pure titanium and those titanium-base alloys which contain 85% or more titanium by weight. The titanium content of other ferrous or nonferrous alloys is not to be reported.

5. At the discretion of the Contractor, DD Form 683 may be duplicated by standard reproduction methods.

6. When filled in, DD Form 683 contains Security Information; the report is classified "CONFIDENTIAL" when requested data has been entered.

7. DD Form 683 is intended as the means of providing the minimum of data required to forecast and compile titanium requirements. The use of titanium and titanium-base alloys in connection with privately financed projects should be reported so that the complete needs will be considered in "Requirements versus Availability" studies. DD Form 683 may be used for reporting privately financed requirements; such uses should be clearly distinguished from military requirements.

8. The requesting department will specify by cover memorandum to the contractor the number of copies to be prepared and to whom they should be forwarded.

9. The submission of DD Form 683, or revisions thereto, will be required semiannually.

10. In the event that no appreciable changes occur which affect the accuracy of a previous submission, subsequent submission of the report (or portions thereof) need not be made. A statement that no changes have been made must be furnished in lieu of the report.

B. Details Instructions

Complete DD Form 683 by filling in the appropriate columns as follows:

Page — of —— pages. Number the pages of each report consecutively.

2. *Contractor's Name.* Enter the name of the prime contractors.

3. *Contractor's Address.* Address of the prime contractor.

4. *Item and Model(s).* Identify the procurement item (or items) for which requirements are forecast. **One report form may be used to represent two or more** models which have identical requirements for titanium. List all appropriate designations. Example: F–100D, F–102, XF–103, and J–57P19W.

5. *Contract Number(s).* List the Military Departments contract number(s) applicable.

85069—56——5

6. *Date Submitted.* Date report submitted.

7. *Part or Part Group.* List the names of the parts, or part groups, which are manufactured from titanium. Part numbers are not required, but the identification of all parts by name and number is desirable. Sufficient information should be provided to identify the functional usage of titanium parts or part groups. Examples:

a. Discs, compressor rotor, Stages 8 through 12.
b. Shroud, cabin heater, 63–71748.
c. Bracket, supercharger mounting.

8. *Specification.* List the specification to which pure titanium or titanium alloys are procured. Commercial designations should be used when applicable; however, contractor's specifications may be listed in the absence of commercial designations.

9. *Form or Shape.* Enter the applicable classification code from the Department of Defense Coded List of Materials, dated September 1953. If the code is not available, list the name of the form or shape specified; bar, sheet, forging, billet, etc.

10. *Unit Gross Weight (lbs.).* For each part, or part group, enter the estimate gross weight, per unit, of each specified material and form of material. Include all losses, such as scrap generated during fabrication, rejections, engineering changes, etc.

NOTE.—*The gross weight of forgings is the weight before machining—but after the removal of excess material as shipped by the producer.*

11. *Unit Net Weight (lbs.).* Enter the weight, per unit, of the finished parts made from the materials listed. Estimated net weights may be used in the absence of actual net weights. Code estimated weights by suffixing the letter "E." As soon as parts are fabricated and weighed, subsequent quarterly reports should record actual weights.

12. *Spares Weight (lbs.).* List the estimated weight of additional materials required for the production of spare parts or assemblies where "spares" can be separately identified or where records are available; otherwise spares material will be included with production requirements (columns "Total Per Quarter for 1st Year" and "Total per half year for 2nd year and total for 3rd year") only.

13. *Total Per Quarter for First Year.* Indicate the total amount of each specified material, including spares, for which delivery from the supplier is required during each of the four quarters of the first year covered by the report.

14. *Total for Second and Third Years.* Enter the estimated quantity by half years for which delivery is required during the second year and total for third year of the period covered by the report.

Note.—For Research and Development or other projects for which gross and net unit weights are not applicable, report *only* the materials required per half year or year.

15. *Status and Remarks.* Specify the status of the listed use of titanium by entering the appropriate symbol in descending order of status:

A. Current production requirements

Based on approved designs released for production.

B. Prototype or experimental requirements

Estimated requirements for the production of prototype, service test, or experimental articles.

C. Research and development requirements

Estimated requirements for all research and development activities other than those which are a part of A, B, or D.

D. Potential requirements

Estimated requirements based on contemplated uses, new planning or design, projects pending test, approval or other considerations, which may or may not result in firm requirements at a later date. Use this column for additional information and remarks which will further the adequate forecast of titanium requirements, which qualifies the data reported, etc. Typical examples:

a. Design subject to cost consideration.
b. Scheduled for test November 1955.
c. Six experimental engines to be built.

For prototype and experimental articles, list contract number and number of articles. For research and development projects, list contract number and brief description of project.

SECURITY CLASSIFICATION

4210.9 (Encl 3)
Nov 9, 55

DEPARTMENT OF DEFENSE

TITANIUM REQUIREMENTS FORECAST

(Titanium and Titanium-Base Alloys)

DATE SUBMITTED

Form Approved Budget Bureau No. 22-R114

PAGE OF PAGES

CONTRACTOR'S NAME

CONTRACTOR'S ADDRESS

ITEM AND MODEL(S)

CONTRACT NUMBER(S)

PART OR PART GROUP	SPECIFICATION	FORM OR SHAPE	UNIT GROSS WEIGHT	UNIT NET WEIGHT	SPARES GROSS WEIGHT	TOTAL PER QUARTER FOR 1ST YEAR (Lbs)				2D YEAR (Lbs)		TOTAL FOR 3D YEAR (Lbs)	STATUS AND REMARKS
						1ST	2D	3D	4TH	1ST HALF	2D HALF		

DD FORM 1 NOV 55 683

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

B29911

SECURITY CLASSIFICATION

The effect of the steel strike on shipments of mill products may be judged from the following remarks of Deputy Assistant Secretary of Defense R. C. Lanphier, Jr.:

> Based on data by Business and Defense Services Administration, Department of Commerce, shipments of titanium mill products for the period January–June 1956 are approximately 10 percent higher than were the estimated requirements for the same period of time. The difference can be accounted for in several ways: First, there was a carryover of orders into the first quarter of 1956 which had been scheduled for shipment in the fourth quarter 1955; and secondly, there appears to continue to be a small rejection rate by the aircraft manufacturers. Material that is returned to the fabricators for further working appears in the shipment reports as a new shipment when the material is returned. This causes some duplication in reported shipments.
>
> It is difficult to forecast at this time whether shipments may exceed estimated requirements during the last half of this year. The strike in the steel industry which affected production for about 6 weeks will reflect lower shipments than scheduled; for example, the July shipment schedule called for approximately 943,000 pounds of mill products, while actual shipments amounted to approximately 383,000 pounds. Producers will make every effort to make up the loss due to the strike by the end of the year, because of the nature of the industry they have a difficult task on their hands.

CONCLUSIONS

1. It is now clear to the subcommittee staff that titanium is rapidly coming of age—perhaps more rapidly than was anticipated in the staff report of August 15, 1955.
2. The recent development of higher temperature resistant titanium alloys will increase its use in military aircraft.
3. The gradual reduction in price, if continued, will stimulate the use of titanium in Army, Navy, and commercial installations and equipment.
4. The extensive experimental programs instituted by the armed services and the Battelle Memorial Institute program are well designed to solve the problems of working titanium.
5. It appears that the staff report of August 15, 1955, was not over optimistic as is indicated by the extensive expansion programs now underway without the use of Government funds.

APPENDIX

The striking progress titanium is making is shown by the many articles appearing in newspapers telling of price reductions and expansion of facilities. One recent article carries the advance notice of the formation of a new company capitalized at $40 million for the operation of a long-sought for continuous process for sponge production. Numerous programs for expansion of production and fabricating facilities demonstrate that private capital now looks upon titanium as good risk, and that increasingly less Government assistance is required to put production on a sound and growing base.

As this report goes to press, it is deemed of sufficient interest to add a selected list of newspaper articles as an appendix. They are only a few out of many scores.

[American Metal Market, December 18, 1956]

Titanium Output Rise in 1957 Seen at 137 Percent by T. W. Lippert of T. M. C.

cites accomplishments in quality, lower prices, capital commitments, mill output, and heat-treated alloy sheet

New York.—The titanium producers have doubled and redoubled production in the past 6 years at a pace unparalleled in the metals industry, states T. W. Lippert, manager of sales and technical service, Titanium Metals Corporation of America, in his analysis of the year's activities. Mr. Lippert observes that the firm goals set for 1957 represent a spectacular challenge of 135-percent increase. About 23 million pounds of mill products are scheduled for 1957 delivery, having an estimated value in excess of $200 million. Sponge production estimates for 1957 range between 56 million pounds and 56 million pounds, either quantity being quite adequate to take care of melting requirements.

(The text of Mr. Lippert's survey follows:)

"The year 1956 was characterized by steeply declining price curves, record-shattering production volume, and very heavy capital equipment commitments to more than double production in 1957. The industry also established new high levels of metallurgical quality, greatly expanded the recycling of mill scrap, and initiated production of heat-treated alloy sheet of unprecedented strength, size, and gage uniformity.

"Production of finished mill shapes, in 1956, totaled 10,600,000 pounds, which was about 25 percent higher than the most optimistic first-of-the-year estimates. The mill products had an estimated market value of $130 million. The record year was particularly im-

pressive in that there was a 4- to 6-week interference in rolling operations caused by the midsummer steel strike.

"To support the 1956 production of 10,600,000 pounds of finished mill products required an output of about 23 million pounds of ingot metal. This, in turn, consumed some 20 million pounds of the pure basic raw material, titanium sponge. The difference of 3 million pounds represented the weight of alloy additions and recycling of titanium scrap.

"Total sponge-metal production, in 1956, jumped ahead to about 29 million pounds, some 9 million pounds more than was required to support finished metal shipments. This excess sponge, of about $28 million estimated market value, was blotted up by in-plant inventory buildups and some governmental contractual purchasing.

"Four melters and processors of titanium metal continued to dominate the market—Titanium Metals Corporation of America, Rem-Cru Titanium, Inc., Mallory Sharon Titanium Corp., and Republic Steel Corp. Two newcomers started operations in 1956—Oregon Metallurgical Corp., at Albany, Oreg., initiated an ingot melting facility, and Harvey Machine Co., Inc., Torrance, Calif., also started ingot furnaces to melt extrusion rounds. For the sponge metal, the major producer was Titanium Metals Corporation of America; others ranged in probable order of output were E. I. du Pont, Electro Metallurgical Co., Cramet, Inc., and Dow Chemical Co.

"EXPANSION

"Sizable expansion plans were announced in 1956 by Titanium Metals Corporation of America and Du Pont. The year's most significant regrouping of companies was the joining of Republic Steel Corp. and Cramet into an integrated operation, which was announced in early June. Late in the year, National Distillers Products Corp. announced plans for building a 5,000-ton-per year sponge plant at Ashtabula, Ohio, and Kennecott Copper Corp. and Allied Chemical & Dye Corp., announced the formation of a joint subsidiary to produce titanium metal. Also, of major significance was Titanium Metal Corp.'s purchase, late in the year, of a plant at Toronto, Ohio, which will be reconstructed as the industry's first facility for rolling and forging titanium exclusively on specially designed equipment.

"The industry continued its dramatic downward price trend in 1956. Titanium Metals Corp. initiated an overall 6 percent reduction in mill-product prices on May 15 and followed with another 6 percent reduction on December 3. On May 15, Titanium Metals dropped the sponge price 20 cents per pound to $3.25, on July 2 Du Pont further reduced the price to $3, and on December 5 Du Pont again reduced the price by 25 cents to $2.75 per pound.

"Japanese imports of sponge into the United States totaled 3,500,000 pounds during 1956, which was over 3 times 1955 shipments. It is expected that imports will step up to an even higher figure in 1957, as deliveries are made under a sizable barter agreement with the Commodity Credit Corporation.

"GROWING USAGE

"The year was marked by growing interest in titanium usage for nonmilitary items, with the electronic and chemical-processing industries particularly active. In military items, actual service performance is greatly exceeding expectations. Practically all advanced aircraft, jet engines and guided missiles are employing large quantities of this very strong, light weight, and corrosion-resistant metal, particularly in those areas subject to high heat.

"All commerical producers of titanium sponge continue to favor the use of either magnesium or sodium as reducing agents in the extractive process. As production mounts and know-how increases these conventional production methods are performing better and better, both costwise and qualitywise. The industry, however, continues its active search foir a revolutionary new extractive procedure having possibilities of very low costs. Electrolytic winning continues to show the greatest promise, and industry observers look for solid achievements in this area during the next 5 years."

[American Metal Market, December 14, 1956]

MALLORY-SHARON UNIT WILL REFINE TITANIUM SCRAP

COMPLETE EVALUATION OF NEW PROCESS TO BE MADE

NILES, OHIO.—One of the Nation's leading producers of titanium mill products, Mallory-Sharon Titanium Corp., of Niles, Ohio, has announced plans for building a large-scale pilot plant for refining titanium scrap, using a new electrolytic process that yields extremely pure metallic titanium. The plant's refining capacity will be large enough to permit complete evaluation of the new process.

Since the beginning of the titanium industry, reuse of scrap has presented a problem. Presently scrap must be carefully segregated, cleaned, and processed, and oxygen or nitrogen contamination cannot be tolerated in view of strict quality requirements. Although titanium producers are melting some scrap in their operations, technical difficulties limit its usability.

As a result, there has never been a market for titanium scrap comparable to that for other metals such as steel, aluminum, copper, and brass. If the new process proves as attractive as it now appears, this scrap situation, affecting the entire titanium industry, will be radically changed.

According to James A. Roemer, Mallory-Sharon president, the process has been proved on a laboratory scale and several hundred pounds of ductile titanium have been produced. One of the main features of the process is that scrap quality appears unimportant, and many grades of scrap can be easily refined. The end product of the process consists of large crystals of extremely pure metal, formed on a steel cathode in a heated electrolytic solution. After refining, the

crystals will be used in Mallory-Sharon's double-melting process in the production of conventional large ingots.

Indicative of the high purity obtained, electrolytic metal with a Brinell hardness of 60 has been made, whereas present commercial titanium has hardness of 120 to 140. Elongations as high as 60 percent have been achieved. This high purity may well lead to new uses for the metal, but in any event will simplify processing.

The basic refining method known as the Dean-Raney process, was developed by Dr. R. S. Dean and Dr. Ben B. Raney, and laboratory work was handled at the Chicago Development Corp. under sponsorship of Mallory-Sharon Titanium Corp. Dr. Dean, one of the pioneers in the titanium field with the Bureau of Mines, has served as consultant to Mallory-Sharon since 1952, concentrating on development of the electrolytic refining process.

Mallory-Sharon officials expect the new plant to be completed by June 1957. As president James Roemer put it: "There is a great deal of evaluation and study to be done when the pilot plant is in operation. Nevertheless, we have enough confidence in the process to invest several hundred thousand dollars in this facility, and we feel that it will lead the way to economical scrap recovery, and a much stronger titanium industry."

Mallory-Sharon is currently engaged in a major expansion program which will increase its titanium melting capacity to 1 million pounds a month by early next year. Titanium and its alloys are being used on a large scale in military aircraft programs, and new uses in industry are being continually developed.

[The New York Times, December 13, 1956]

Allied Chemical, Kennecott Form Subsidiary To Produce Titanium

PLANT WILL USE NEW CONTINUOUS PROCESS TO TURN OUT METAL—$40 MILLION INITIAL INVESTMENT IS PLANNED

The Allied Chemical & Dye Corp. and the Kennecott Copper Corp. are forming a joint subsidiary to produce titanium metal by means of a new continuous process.

This was announced yesterday by Charles R. Cox, president of Kennecott, the Nation's largest copper producer, and Fred J. Emmerich, president of Allied, a leading manufacturer of industrial chemicals. They said an initial investment of $40 million was planned for the equally owned subsidiary, with further expansion to be undertaken as industry demands developed.

A plant will be built at a site to be announced soon, the announcement said. By late 1958 the plant is expected to begin producing titanium tetrachloride, an intermediate chemical material from which the metal is derived; titanium sponge, the primary form of the metal, and titanium metal billets, which are produced by melting the sponge in a vacuum. Billets are the form of metal from which mill products such as sheet, ulate, rod, wire, and tube are fabricated.

Of considerable interest in the titanium industry was the announcement that a continuous process for making the metal had been devel-

oped. All titanium produced commercially today is made in batches by methods that reduce titanium tetrachloride with either magnesium or sodium within reactor vessels.

The continuous process was developed by Allied Chemical's Solvay process division and will use sodium as the reducing medium, the announcement said. Officials of the company declined to describe the process further at this time except to say that it was a "truly continuous 24-hours-a-day, 7 days-a-week operation."

Mr. Cox and Mr. Emmerich also announced that Allied Chemical had developed an improved process for the manufacture of titanium tetrachloride that permits the use of titanium slag as the raw material. Kennecott is part owner of the Quebec Iron & Titanium Corp., which mines and processes iron-titanium ore to produce pig iron and titanium slag. The latter is one of the starting materials for making titanium pigment, a whitening agent used by a long list of industries, and titanium metal.

Kennecott and Allied Chemical did not disclose what production capacity was planned for the titanium plant. Production of the strong, light metal from the 5 concerns now making it is expected to reach 14,500 tons of the primary sponge form this year. More than 90 percent of the titanium mill products being turned out are used by the aircraft industry.

[Wall Street Journal, August 10, 1956]

Republic Steel Plans an $8 Million Expansion of Titanium Facilities

By a Wall Street Journal staff reporter

Cleveland.—Republic Steel Corp. announced an $8 million program for boosting its titanium melting, preparation, forging, and laboratory facilities at Canton and Massillon, Ohio.

The program will raise Republic's output of titanium ingots and alloys to approximately 12 million pounds or 6,000 tons yearly. A Republic spokesman estimated the expansion would quadruple the company's present titanium metal producing capacity. Republic's titanium products include bars, wire, forging billets, plates, sheets, and strip.

Expansion at Canton and Massillon follows acquisition by Republic earlier this year of a half-interest in Cramet, Inc., from the Crane Co. Cramet has facilities at Chattanooga, Tenn., to produce 6,000 tons of titanium sponge annually. Republic also is developing in southwest Mexico an important deposit of rutile, a rich titanium-bearing ore.

The acquisition of an interest in Cramet made Republic an integrated producer of titanium. To produce titanium metal, ore such as rutile and ilmenite are concentrated and then refined by a chemical process into almost pure titanium sponge. The sponge then is melted to produce titanium metal and fabricated into products. Republic's operation's at Canton and Massillon start at the sponge-melting level.

The initial phase of the expansion at the Ohio cities already is in progress and is expected to be completed this fall. The entire program is scheduled for completion in the fall of 1957. It is covered in large part by a certificate of necessity granted to Republic by the Office

of Defense Mobilization, permitting accelerated depreciation of the new facilities.

When completed the new facilities will provide employment for approximately 400. Most of the new facilities will be at Republic's south division plant in Canton. However, bar rolling finishing facilities will be added at the Massillon steel plant. Major facilities to be added include 12 melting furnaces.

Titanium is a strong, lightweight metal. About 95 percent of United States titanium production now goes into military aircraft, but the metal is being used increasingly in such industries as civilian aircraft, chemical, marine, food processing, pharmaceutical, atomic power, electronics, and petroleum.

[American Metal Market, December 13, 1956]

L. Barron of Du Pont Sees Nondefense Use of Titanium Growing

Wilmington.—L. J. Barron, pigments department of E. I. du Pont de Nemours & Co., Inc., stated at the symposium here last Friday that nondefense titanium application is becoming a significant factor in the overall titanium picture.

He emphasized that as prices continue to drop, titanium will take a major place as a standard material of construction for industry.

The Du Pont spokesman said:

> Fabricators have gained experience and confidence. As an example, this is a list of over 200 sources for various non-defense titanium items ranging from spray nozzels to heat exchangers. Competitive bidding on titanium construction has now become the rule rather than the exception.

Mr. Barron noted that the first real and industrial application of titanium was a tubular unit installed in an F–84 Thunderjet in 1951. He said that it was hoped that the titanium would last about 18 months and he emphasized that it is still operating after 5 years of continuous service.

Among the applications outlined by Mr. Barron were those in paper industry, food, or beneficiation, pharmaceutical, petroleum, anodizing, atomic energy fields and marine hardware.

[American Metal Market, December 13, 1956]

Titanium Ingot Use in 10 Months 7,800 Net Tons

SHIPMENTS OF MILL PRODUCTS GAINED IN OCTOBER

New York, December 12.—Production and shipments of titanium mill products gained slightly during October, according to data issued by the United States Department of Commerce in Washington. Total production in October amounted to 1,313,096 pounds as against 1,070,939 pounds in September. The respective figures for shipments were 1,324,085 pounds and 1,068,341 pounds.

For 10 months, production amounted to 6,793,386 pounds and the shipments during that period amounted to 7,662,164 pounds.

Production of titanium ingot totaled 2,715,451 pounds in October, compared with 2,166,567 pounds in September. Domestic consumption of ingot totaled 2,624,883 pounds in October.

Ingot production for 10 months of this year amounts to 15,589,830 pounds.

The following table shows titanium mill products data for 10 months in pounds:

	Pounds
Sheet, plate, strip	2,566,377
Forging, extrusion, billet	3,125,437
Rod, bar, and wire	1,970,350
Total	7,662,164
Ingot production	15,589,830
Mill production	6,793,386

SHIPMENTS IN POUNDS

Data for October and September follow in pounds:

	October	September
Sheet, plate, strip	346,355	278,658
Forging and extrusion billet	604,106	514,919
Rod, bar, and wire	373,624	274,764
Total shipments	1,324,085	1,068,341
Total production	1,313,096	1,070,939

[American Metal Market, December 12, 1956]

Titanium's Corrosion Resistance

By H. B. Bomberger and Dwight Kaufmann,
Rem-Cru Titanium, Inc., Midland, Pa.

(Summary of a talk presented at the Du Pont symposium on titanium in Wilmington, Del., on December 7, 1956)

Laboratory and field tests show that commercial titanium has outstanding resistance to natural environments and many chemicals. Some of the most interesting of these are the chlorides, hydrochlorites, and wet chlorine. The few known chemicals that attack titanium rapidly are primarily the strong reducing acids and ionizable fluoride compounds. Certain contaminants or process ingredients can have a marked effect on the resistance of titanium to commercial solutions. Consequently, it is advisable to field test the metal prior to extensive usage. In general, the effect of certain salts and oxidizing agents is to inhibit corrosion. Furthermore, the metal has the ability to polarize readily to the potential of other materials, permitting dissimilar metal contact under some conditions. Also, under an anodic current, the metal usually becomes even more resistant, allowing its use in some severe anodizing operations with excellent success.

Thus we see that titanium, while basically a very active metal, is unusually resistant to a wide variety of mediums, and the designer of chemical equipment is provided with a new and important material

of construction. Being an active metal, titanium is, as one might expect, not at all easy to reduce from the ore. The process, as is well known in the pigments department, is complex and expensive. Therefore, in its early years, the cost of this metal with such attractive properties has been high.

Fortunately for the chemical engineer, titanium not only has a high order of corrosion resistance, but it also is unusually strong, particularly at moderately elevated temperatures, and it is relatively light in weight. Even at room temperature commercially pure A–70 titanium has a yield strength of about 80,000 pounds per square inch at 0.2 percent offset, compared to about 35,000 pounds per square inch for annealed 18–8 stainless steel—and it weighs only 56 percent as much.

JUDICIOUS ALLOYING

This fact, plus the even greater gains brought about by judicious alloying, has made titanium quite attractive to the designer of airplanes and jet engines. Today, every new plane and almost all new engines are utilizing increasing quantities of titanium in their design. The production of titanium mill products has jumped from a few hundred pounds in 1950 to approximately 5,000 tons in 1956, and probably will be over twice that in 1957.

This has brought the price of titanium down far faster than could have been possible without the support of our fabulous aircraft industry. But in spite of some preoccupation with this big user of our products, we, as a manufacturer of titanium sheets, strip, bars, tubing, wire and other wrought forms, and perhaps castings in the not too distant future, recognize that the chemical industry is even more important as a user of this versatile metal. Let's look at some of the places where titanium already has proven itself in the chemical field.

One exhibit shows an application which pigments found right in its own back yard, in parts for steam-jet diffusers for hydrochloric-acid service. The best materials used previously lasted 3 months. The titanium diffusers have been in service 4 years and are going strong.

Another exhibit shows a valve for controlling a highly corrosive fluid at 3,000 pounds per square inch pressure. A stainless steel valve lasted 70 hours. The titanium valve lasted 70 days—24 times as long. With stainless the process wasn't practical; with titanium it was.

Another interesting application involves calcium hypochlorite. Involved are two parts of a filter press used by Penn Salt. The one on the left is type 316 stainless after 30 days, badly pitted. The one on the right is titanium after 7 months—no pits at all, and the original tool marks still plainly visible.

At the Chambers works, titanium was put to work in 60 percent nitric acid at 480° F. and 300 pounds per square inch pressure. As indicated previously, while stainless is fine in reasonably hot 60 percent nitric, it breaks down when the temperature and pressure go up. In this case, it lasted 6 months. A titanium "top hat" for the condenser has been in service for 2½ years and is performing as expected.

Still another application—this time in 3½ percent hydrochloric acid, plus wet chlorine—at Wyandotte Chemical, where a Hastelloy impellor lasted 6 months. The titanium unit, fabricated by Wyandotte

themselves without any difficulty, has been in operation for over a year with no sign of trouble.

With such good results in several small trials of this type, Wyandotte saw the light and has started switching to titanium in such things as the heat exchanger. This is used to cool a 15 percent solution of sodium hypochlorite, and the results have delighted Wyandotte's engineers.

PAYING DIVIDENDS

These are just a few of the many places where titanium already is paying handsome dividends in increased service life. Another very important consideration is elimination of down time. Take, for example, the thermowell. It isn't very big—and only costs $95, in stainless steel. But every time it failed, which was every 6 to 12 months, a Du Pont plant took a $1,500 loss due to production down time and labor cost. Even if a titanium unit lasts only 5 years—and it probably will last much longer—there is a potential savings of perhaps $10,000. Worth thinking about?

Now we have been extolling the virtues of this new metal at some length; it should be pointed out here that titanium is not a cure-all for all corrosion problems. It is not very resistant to such things as hydroflouric acid, boiling concentrated formic acid, hot hydrochloric or sulfuric acid, hot oxalic or concentrated hot phosphoric acid, particularly when these chemicals are in the pure state. However, it is surprising what a difference a small quantity of an oxidizing agent, such as may be found as a contaminant in many industrial solutions, will make.

Therefore, even though in the laboratory results may not be too good in reducing acids, frequently titanium will far outlast other metals in actual service. Field trials in many chloride solutions, oxidizing acids, bleaching agents such as chlorine, dioxide, and the like, have given excellent results.

It is suggested, therefore, that the details of operations where other metals are not standing up well be reviewed with a Rem-Cru engineer. If results of tests under similar conditions are not available, a service trial can be arranged.

One question which I am sure has been going through your mind is: "Sure, titanium is remarkably corrosive resistant, in fact, practically inert in mediums which attack stainless, Monel, or Hastelloy, but what about cost? Isn't it terribly expensive? How about fabrication?" And so on.

Let's take the last one first. Titanium can be fabricated much like stainless steel. It can be formed, machined, welded—using heliarc or other inert-arc methods—and dozens of companies have produced all kinds of equipment from it. Remember the Wyandotte heat exchanger, for example.

STOCKS ON THE SHELF

One problem still existing is the fact that you cannot yet call one of a dozen warehouses and buy titanium sheets off the shelf. However, stocks of all sizes of sheet, bars, tubing, etc., are building up rapidly at the plants.

As to cost, as we said earlier, titanium is expensive to refine. But in just 5 years the price has been cut in half—sheet down from $25 per

pound to about $12.50, and billets down from $20 to less than $9. Still expensive? Yes; but let's look further.

Since titanium weighs only about one-half as much as stainless, you get almost twice as many square feet per pound. And remember that the cost of almost anything today is largely wrapped up in the labor required to construct it. So, theoretically, titanium equipment should cost only about three times as much as similar stainless equipment.

For once, theory proves to be a fact. You can buy titanium reactors from Pfaudler for just about three times the cost of a stainless unit. Chempump Corp. offers a hermetically sealed titanium pump for just one and one-half times the price of a stainless pump; in fact, at the same price as a Hastelloy B pump. Remember the thermowell mentioned previously? The stainless one cost $95; the titanium one, on the first try, was $300.

CHEAPER TITANIUM

Remember also that while the price of stainless and other common metals continues to increase from year to year, titanium is getting cheaper. So, at a difference in cost of only 3 times or so, and with service life 5, 10, or even 50 times as long, with resultant initial savings, plus elimination of down time which usually is by far the most expensive item, our question is, "Can you afford not to use titanium?"

Cost analysis of stainless versus titanium

	A. I. S. I. type 316 stainless steel	Rem-Cru A 70 titanium	Cost factor
Price per pound .0625 sheet 1,000-pound quantity.	$0.8325	$15.10	18.1
Adjusting to price per sheet...	Density, 0.286 lb./in³ 62.8 lb./sheet.	Density 0.163, 35.4 lb./sheet	10.1
Assuming material costs are 20 percent of finished assembly in stainless.	Materials=X. Fabricating =4X. Finished assembly =5X.	Materials=10.1X. Fabricating=4X. Finished assembly=14.1X.	Less than 3

[American Metal Market, December 8 and 11, 1956]

Titanium Fabricating Techniques Stressed at Du Pont Symposium

By L. S. Busch, director of research, Mallory-Sharon Titanium Corp., Niles, Ohio

The first installment of the text of Mr. Busch's address at the Du Pont symposium is given below:)

COMPARISON WITH STAINLESS STEELS

Titanium-base materials are often compared with stainless steels partly because the two types of material have in common excellent corrosion resistance at normal and slightly elevated temperatures and are thus considered for the same type of applications, and partly because the technological problems involved in working and machining them are similar. There is, however, no marked fundamental similarity between them. In the matter of density the advantage is on the side of titanium as we have already seen, the density of stainless steels being approximately 8 gm/cc. compared with 4.5 g/cc. for titanium. Conse-

quently, for room-temperature applications requiring strength alone, a part made of titanium need have only 60 percent of the weight of the equivalent part in stainless steel, since equivalent strengths can be obtained in both titanium-base materials and steels if suitable alloys are chosen. When rigidity is important, however, titanium loses a large part of its superiority, owing to its low elastic strength. At elevated temperatures, furthermore, the loss in strength suffered by titanium-base materials tends to be greater than that observed in stainless steels.

In the matter of technology, the apparent similarities between stainless steels and titanium can be explained in terms of their closely similar thermal conductivities. Both the thermal and electrical conductivities of stainless steels are far lower than those of normal structural materials. It is not surprising, therefore, that the many difficulties, experienced in hot working, heat treating, and machining titanium, which arise from its poor thermal conductivity, are shared by stainless steels. The manipulation of stainless steels is made easier in some respects, however, by the higher Young's modulus of these materials. Thus the elastic distortion experienced in machining, and the spring back to be allowed for in sheet-forming operations on stainless steels, will only be half that for titanium. In spite of general similarities in the working characteristics of the two types of material, therefore, the same tools cannot always be used for both.

There is one other area of industrial use where titanium has an edge over stainless steel, and that is resistance to corrosion by chloride solutions. Titanium just is not attacked by sea water at room temperature or slightly above. There are also other corrosive mediums where titanium excels stainless steel in corrosion resistance, and this field is the most promising for commercial or nondefense applications.

CRYSTAL STRUCTURE

Titanium exists in two crystal forms which transform one to the other at 882° C. Below this temperature the metal has a hexagonal crystal structure which is essentially of the close-packed type but has an exial ratio of only 1.587 instead of the ideal value, 1.633. In the low-temperature form (known as alpha), metallic titanium cannot, therefore, be regarded as being made up of ideally close-packed spreically symmetrical atoms. It will not, furthermore, be isotropic, and many of the physical properties of the material will thus be dependent on the direction within the crystal for which they are measured.

The high-temperature form of titanium (beta) has a body-centered cubic-crystal lattice. In the unalloyed state beta titanium cannot be retained at room temperature, and direct comparisons between the properties of alpha and beta titanium at the same temperature cannot, therefore, be made.

ATOMIC VOLUME

The atomic volume per atom at room temperature may be calculated for both alpha and beta titanium from the measured and derived lattice parameters given above. The values are found to be $17.65A^3$ for titanium in the alpha form and $17.69A^3$ for the beta form. It would be expected, therefore, that there would be relatively little volume change when one form of metal changes in the other.

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DENSITY

The calculated value for density comes out as 4.505 gm./cc., which agrees well with the result obtained by pyknometric measurement. When this figure is compared with 7.88 gm./cc. for steel, the potential advantage of titanium for aircraft use is readily apparent. Aluminum, however, has a density of 2.7 gm./cc., and mechanical properties superior to those of aluminum alloys are thus required to justify the use of titanium. Density generally would not affect the choice of a metal for corrosion resistance.

INTERATOMIC BONDING

The reason why the density of titanium is so much lower than that of iron is only partly due to the lower atomic weight of titanium. A major part of the difference must be attributed to differences in the bonding between the atoms in the two metals. That such differences exist is apparent from the fact that, though the forces binding the titanium atoms together, as measured by the latent heat of vaporization, are greater in titanium than in iron, the titanium atoms are, nevertheless, farther apart. This is one of the factors which must await a greater knowledge of electronic processes in transition metals for its explanation. The greater bonding forces in titanium, however, can account for its resistance to destruction by corrosion, stress, and heat. The greater distances between atoms can account for the ease of diffusion of gases into the metal but also for its generally higher tolerance for hydrogen, oxygen, and nitrogen as compared to iron.

YOUNG'S MODULUS

Because titanium atoms are relatively widely spaced, the possible curvature of the unit cell is smaller in metallic titanium than in iron, and its elastic strength is, therefore, correspondingly smaller. Thus the mean Young's modulus for titanium is 15.5×10^6 pounds per square inch, whereas iron-base materials may have values almost twice as great as this. On the other hand, the elastic strength of titanium is not abnormally low compared with metals other than iron, since aluminum, copper, and brass have Young's modulus values of 10, 16, and 15×10^6 pounds per square inch, respectively.

ELECTRICAL RESISTIVITY

The electrical resistivity for unalloyed alpha titanium at room temperature is 45×10^{-6} ohm. cm., which is remarkably high for a pure metal. Copper and silver, for instance, have room temperature resistivities of 1.62×10^{-6} and 1.72×10^{-6} ohm. cm., respectively, and even aluminum (2.82×10^{-6}) and iron (9.8×10^{6}) are appreciably better conductors than titanium. In fact, among elements which conduct electricity, only the semimetals, such as antimony (42×10^{-6}) and bismuth (120×10^{-6}), have resistivities comparable with that of alpha titanium. Austenitic stainless steels, however, with resisistivities of about 80×10^{-6} ohm. cm., are equally poor conductors.

THERMAL CONDUCTIVITY

Since thermal energy is distributed in a metal largely by means of the free electrons, thermal and electrical conductivities are closely related.

Thus, titanium, having poor electrical conductivity, must be expected to show poor thermal conductivity. It is, in fact, only 0.038 cal/cm. sec. deg. C. compared with 0.92 for copper, 0.50 for aluminum, and 0.16 for iron. Austenitic stainless steels are again the only common structural metals which have thermal conductivities comparable with that of titanium.

SPECIFIC HEAT

A value of 0.125 cal/gm./ deg. C. has been obtained for the specific heat of alpha titanium at room temperature. With regard to this particular property, therefore, titanium does not appear to be unusual, probably because at temperatures appreciably above absolute zero the electrons make a relatively small contribution to the total specific heat of a metal, and it is in the more directly electron-dependent properties in which titanium may be expected to differ from most other metals.

THERMAL EXPANSION

The temperature coefficient of linear thermal expansion for polycrystalline alpha titanium is about 8.4×10^{-6}/ deg. C., but it cannot be given with great accuracy since it is dependent on crystal direction.

TECHNOLOGICAL ASPECTS—MELTING AND CASTING

The melting point of titanium (~1670° C.) is higher than that of any metal at present in use as a structural material. Though this fact, which promised good high-temperature strength, played a major part in bringing about the industrial development of titanium, it means that the problems involved in melting the metal on an industrial scale are bound to be more severe than those normally encountered, since increasing temperatures result in higher reactivity and consequently greater difficulty in finding materials capable of containing the melt. With titanium, moreover, such difficulties are greatly magnified by the unusually high chemical reactivity of the metal at elevated temperatures; in fact, the problem of finding a refractory material which can resist the attack by liquid titanium has proved to be very difficult. Industrial melting techniques completely different from any previously applied have had, therefore, to be developed for titanium.

The problem of preventing reaction between liquid titanium and the material which contains it has been solved by the use of a water-cooled copper crucible, and to insure that the container is a much lower temperature than the melt; in other words, heat is extracted so rapidly from the container that its temperature remains too low for metallurgical reaction to occur in spite of the high temperature of the titanium with which it is in contact. The successful operation of such a technique depends entirely on the relative rates at which heat enters the container from the melt and is extracted from the container by the

cooling water. The low thermal conductivity of titanium is an advantage since the molten metal can flow freely within the container until it contacts the cooled surface of the container, whereupon a shell of the metal must be presumed to solidify. The thermal conductivity of titanium, however, is so poor that this shell is very thin, and the melt fills the container very much as though complete wetting of the copper surface took place.

In the process by which the ingot is built up by the progressive additions to the charge of metal within the container, the low thermal conductivity of the metal is again an advantage. No increase of heat imput is necessary as the ingot grows, since the heat is largely confined to a molten region just below the arc and it is easy, therefore, to maintain quite a large volume of the metal in a molten condition.

However, these melting problems have greatly hampered the development of an economical casting furnace. Even today, to my knowledge, there is no real answer to the problem of maintaining a large volume of molten titanium in such a way that pouring of castings can readily be accomplished. Molds have been developed, but a successful and economical casting furnace is yet to be operated.

WORKING PROCESSES

Working is essentially the plastic deformation of a metal under the influence of restraints which cause the deformation to take place in a predetermined manner.

Since deformation usually occurs more easily at high temperatures than at low, working processes are very frequently carried out at elevated temperatures. In considering the working of titanium-base materials, therefore, problems of heat transfer and heat distribution immediately arise. As a result of titanium's low thermal conductivity the flow of heat in the metal under the influence of a temperature gradient will be very much slower than that observed in other metals. Heating times prior to hot working will, therefore, be longer. This is somewhat unfortunate, as the strong tendency of titanium to react with atmospheric gases and any refractory material with which it comes in contact makes it desirable, from all other points of view, that the heating time should be as short as possible.

MACHINING

Machining differs in principle from working in that the deformation of the metal in a machining operation is highly localized, the rate of deformation is higher, the load is sufficiently great to cause fracture and, furthermore, the operation is usually carried out at room temperature.

The high rate of severe localized deformation which takes place immediately in front of the tool tip will bring about a rapid increase in the temperature of this region and since the forces at the point of contact between the tool and the work are high, conditions are ideal for galling. Consequently any measure which reduces the amount of heat generated near the tool tip or which increases the rate at which heat can be extracted from this region will greatly decrease the amount of galling that will take place. Conditions are unusually

severe in the case of the machining of titanium owing to the poor conductivity of the metal which insures that the greater part of the heat generated in the deformed region remains localized. Hence the design of the tool for work with titanium is particularly important. In machining operations, however, it is fairly easy to arrange for effective cooling at the point of contact between tool and work by means of a liquid coolant, and there is litle need for galling problems to arise in machining titanium if suitable precautions are taken. The above information accounts for the early difficulties encountered in the machining of titanium. Today, most well-equipped machine shops find titanium about as easy to machine as stainless steel.

WELDING

Since titanium reacts with all gases (other than the inert gases), flame welding is not possible in titanium-base materials. All the electrical welding techniques may be used, however, and for once, the characteristic properties of the metal are favorable to some aspects of these processes. Provided a suitable blanket of inert gas is used to protect the joint from contamination, it is a fairly simple matter to produce welds of sound physical construction in titanium and its alloys since the high electrical resistivity of the metal assures high heat generation and its low thermal conductivity prevents rapid dissipation of the thermal energy produced. In spot welding of titanium, for example, higher penetration than usual is obtained.

Although in welding titanium the heat-affected zone is restricted by the slow conduction process, within this region temperatures tend to be very high and considerable grain growth occurs. In order to restrict grain growth, and also to reduce the risk of atmospheric contamination as much as possible, auxiliary cooling in the form of a copper-backing block is often provided. In welding titanium alloys the biggest disadvantage arising from the physical characteristics of titanium is due to the occurrence of the change in crystal structure on heating and cooling. On heating, all commercial titanium alloys take on the body-centered cubic structure, and in nearly all instances this must be converted back to the hexagonal phase, or a mixture of two phases, on cooling. In the normal processing of an alloy, of course, care can be taken to insure that this change occurs in such a way as to give the best possible mechanical properties in the cooled structure. In welding, however, the cooling process will take place in an uncontrolled and nonuniform manner; hence undesirable properties may result in the transformed beta phase material. Weldable alloys are now available, and the unalloyed grades are readily weldable.

SUMMARY

The general and basic physical properties of titanium have been discussed and their effect on the working and use of this new metal have been pointed out. Generally, fabricating technology has been developed so that reliable material is available and it is hoped that titanium will find expanded usage in the industrial processes with which you are familiar.

[American Metal Market, December 8, 1956]

Titanium Head Formed by Lukens

Coatesville, Pa., December 10.—The day of widespread use of titanium, the new metal, was brought a step closer today when the Lukens Steel Company announced that for the first time in history a head of solid titanium was formed without the use of costly dies and stamping equipment.

Head shapes are used in a variety of industrial equipment to close up the ends of cylinders. Titanium, one of the most corrosion resistant of all metals but still largely in the developmental stage, hitherto has been used chiefly in the aircraft industry.

But by forming a titanium head using highly versatile spinning equipment in the crucial stages, Lukens has broken a major cost-barrier on the way to broadening the use of titanium notably in the chemical and other process industries. Prior to Lukens announcement, titanium heads were made only with dies which had to be individually built for each variation in size and shape.

In a research program conducted jointly by Lukens and Rem-Cru Titanium, Inc., a Rem-Cru A–55 commercially pure titanium plate was placed on a spinning machine and worked at a minimum temperature of 600° F. The plate had previously been heated under close temperature control at 1,400 to 1,450° F. Then with standard equipment an elliptical-shape head was spun 16 inches in diameter and one-quarter-inch thick.

Initial tests were successfully completed at the Coatesville plant where the industry's first heads were spun more than two generations ago and where the world's largest heads are spun today.

After further tests the titanium head will be shipped to Rem-Cru's plant in Midland, Pa., for further experimental work.

[American Metal Market, December 6, 1956]

Titanium Sponge Price Cut 25 Cents a Pound by Du Pont

Wilmington, December 5.—A reduction of 25 cents a pound in the price of top-grade titanium metal sponge was announced today by the Du Pont Co.

Dr. J. B. Sutton, specialty products sales manager for Du Pont's pigments department, said the price of grade A–1 sponge will be cut from $3 to $2.75; grade A–2, from $2.70 to $2.50; and grade A–2 fines from $2.30 to $2.25.

Dr. Sutton said today's price reductions were in line with the company's continuing policy to provide improved titanium metal at lower costs as the volume increases.

When first introduced by Du Pont in 1948, titanium sold for $5 per pound. The present price represents reductions aggregating 45 percent.

[American Metal Market, December 4, 1956]

TITANIUM METALS CORP. REDUCES PRICES ON MILL PRODUCTS BY 6 TO 8 PERCENT

MEANS IMPORTANT SAVINGS FOR CONSUMERS—SECOND CUT THIS YEAR AND FIFTH REDUCTION SINCE FEBRUARY OF 1954

NEW YORK, December 3.—Titanium Metals Corporation of America has announced price reductions of 6 to 8 percent for titanium mill products, effective today. This is the second price reduction initiated in 1956, and the fifth since February 1954. Sheet prices are down $1 per pound; strip, a minimum of $1.10; plate, 75 cents per pound; bar and billet from 55 to 75 cents per pound; and certain sizes of wire have been reduced $2 per pound. The company attributed these reductions to cost improvements achieved by volume production of mill products, increasing technical know-how, and technological advances in vacuum melting, utilization of scrap and continuous rolling.

Titanium Metals Corporation of America, which is jointly owned by Allegheny Ludlum Steel Corp. and National Lead Co., indicated that its latest price action will effect a $3 million saving for its customers.

HEAVY DEMAND NOTED

Titanium metal is today in very heavy demand, with orders absorbing all of the production from facilities which are being rapidly expanded. TMCA recently announced that it is expanding to a 9,000 tons per year sponge capacity at its Henderson, Nev., plant, and ingot capacity is being increased from 6,000 to 11,000 tons yearly. Last month the company announced the purchase of a former steel mill at Toronto, Ohio, for conversion into the industry's first exclusive titanium alloy forging and alloy sheet rolling facility.

BASE PRICES

Under the new price schedule, titanium sheet base prices per pound are:

	Per pound
Ti–55A	$12.10
Ti–65A, Ti–75A	11.60
Ti–100A	12.00
Ti–140A	14.75
Ti–6Al–4V	14.75
Plate:	
Ti–55A	9.75
Ti–65A, Ti–75A, Ti–100A	9.25
Ti–140A, Ti–150A, Ti–155A	11.25
Ti–6Al–4V	11.25
Wire:	
Ti–55A	9.00
Ti–65A, Ti–75A, Ti–100A	8.50
Ti–140A, Ti–155A, Ti–6Al–4V	11.00
Strip:	
Ti–55A	11.50
Ti–65A, Ti–75A	11.00
Ti–100A	11.40

Bars:	
Ti–55A	7.35
Ti–65A, Ti–75A, Ti–100A	7.10
Ti–140A, Ti–150A, Ti–155A	7.10
Ti–6Al–4V	7.30

The above are subject to size and quantity extras.

[American Metal Market, December 4, 1956]

GM Uses Titanium in Experimental Car

Cleveland, December 3.—For the first time in automotive history, titanium has been used on a direct and large scale in an automobile in General Motors' experimental "family car of the future," the Firebird II.

The revolutionary new automobile contains an all-titanium body. Wide titanium sheets specially produced for the Firebird II were made by Republic Steel Corp., at its titanium plant at Canton, Ohio.

The Firebird II was designed, according to Harley J. Earl, vice president in charge of General Motors styling staff, as a "bold experiment in the possibilities of tomorrow's highway travel."

In addition to the all titanium body, it has a 200-horsepower gas-turbine regenerative type engine, a specially designed automatic starting system, all-metal brakes, a new concept of automotive suspension than incorporates individual wheel suspension and air-oil suspension units, central hydraulic system, and other features.

Of the materials considered for the body of the Firebird II, Robert F. McLean, chief designer, research studio, General Motors Styling Center, said, "By far the most challenging was the relatively new industrial metal—titanium. Its two outstanding characteristics are low specific weight and tremendous corrosion resistance."

In developing a unique automobile body on the Firebird II, GM styling experts decided it should not have a painted surface. "It was felt," Mr. McLean said, "that titanium could be seen to best advantage and its corrosion resistance emphasized if the surface were left unpainted. Consequently, a brushed satin finish resembling silver was decided upon for the Firebird II."

Mr. McLean believes the present cost of titanium prohibits its wide use in production automobiles at present. "However," he said, "as titanium prices decrease, there is no doubt that titanium's great corrosion resistance combined with low specific weight and high yield strength make it well suited for application to many products in the transportation industry."

Thomas E. Perry, Republic titanium metallurgist, in a recent paper discussing the use of titanium in the Firebird II, said, "It is encouraging to see the start of a titanium evaluation program in the automotive industry.

"The use of titanium alloys in bar form at high-strength levels along with low density and extreme toughness suggests further fields of exploration in the internal combustion engine. Intensive reasearch is providing improved techniques for brazing, welding, heat treating, case hardening, and forming titanium."

[American Metal Market, November 30, 1956]

Titanium Mills Seen Prepared for Defense Call

NEED FOR SHIFTING OF SOME DELIVERIES INDICATED

Washington, November 29.—The expanding United States titanium industry will be able to meet anticipated increased requirements of defense contractors next year and in succeeding years, members of the Titanium Producers and Fabricators Industry Advisory Committee said at a meeting yesterday with officials of the Business and Defense Services Administration and other Government agencies.

The committee estimated that titanium melting capacity at the end of 1957 will be sufficient to produce ingots at a rate necessary to meet requirements. Currently the forms and shapes of titanium mill products being produced are rolled or extruded for the most part on equipment that also is capable of rolling or extruding steel products. Committee spokesmen voiced the belief that such equipment can take care of the needs of defense contractors.

Government officials, concerned with production and delivery of titanium products for contractors and subcontractors engaged in aircraft production, told the committee that such production is being hampered seriously by deliveries of titanium which are not in accord with production schedules. Steps will be taken, it was stated, to prevent deliveries of rated orders for titanium fabricated products too far in advance of the time they are needed. This may involve rescheduling of orders placed for deliveries beginning in April next year.

A Government representative also said that rated orders have been placed by contractors or subcontractors for certain products to the neglect of other products, and that in order to achieve the proper flow of titanium from the producers and fabricators it will be necessary to strike a balance in the coming months.

Titanium is a strong, heat-resistant metal that is relatively light in weight, with certain characteristics which make the metal valuable in numerous military and other applications. The industry has expanded substantially in the past 3 years, under the impetus of a Government-sponsored expansion program.

[American Metal Market, November 9, 1956]

Civilian Needs for Titanium Actively Probed

MARTINO OF NATIONAL LEAD SEES OUTLOOK PROMISING

New York, November 8.—The nonmilitary market for titanium is being explored with energy, many test runs and prototypes are being made, and as prices move downward more and more of these markets will require progressive increases in titanium capacity, Joseph A. Martino, president of National Lead Co., today told the New York Society of Security Analysts at the Waldorf-Astoria. He stated that the new metal was advancing toward industrial maturity and a promising future.

Beyond the immediate military need lies the broad nonmilitary base which is the titanium industry's target for tomorrow, he explained. Excluding civilian aircraft, only a small part of current titanium output goes into civilian use.

"The problems of sponge quality, which were so often major points of troubled discussion only 2 short years ago, are now so well in hand as to be completely ignored in technical and industry meetings," he said. Today, titanium is being machined and ground in large quantities, without comment, and often more easily and efficiently than steels of comparable strength levels. Welding, which a couple of years ago seemed almost impossible, is today well along toward being routine. Large-scale recycling of home and customer scrap is now commonplace, whereas in late 1954 many industry authorities doubted whether the problem could ever be conquered.

The general quality of mill products is now often without peer in the metals industry, emphasized Mr. Martino.

"The titanium industry is very proud of this record. It has materially helped our country's defense effort, and definitely accelerated the design of aircraft and ballistic missiles."

To speed the trend in alloy sheet, Titanium Metals Corporation of America only a few weeks ago purchased an entire plant at Toronto, Ohio. Engineering is well along to convert this plant to a model titanium processing facility, first for alloy sheet and forgings, and later to accommodate many titanium products not now being produced or being produced only on a small scale.

TMCA has always been integrated—ingots from its own facility at Henderson, Nev., are converted to mill products in one of its parent's plants. Now TMCA is further refining this integration by establishment of the first finishing facility devoted exclusively to processing titanium into mill products. It is likely that a similar trend will be evident elsewhere in the industry in the near future, the National Lead executive stated.

Mr. Martino said that titanium metal has sprinted from a laboratory oddity to a prominent engineering metal, all in the short space of less than 6 years.

(Extracts of Mr. Martino's address follow:)

"All of National Lead Co.'s activities involving the metal titanium, and related products, are concentrated within Titanium Metals Corporation of America. National Lead Co. owns one-half of TMCA. The other half is owned by Allegheny Ludlum Steel Corp., which also placed all of its titanium metal activities within the TMCA framework, when that corporation officially became operative in March of 1950.

"ALLEGHENY LUDLUM

"One-half ownership in such a prominent activity is somewhat unusual for National Lead Co., and it is equally unusual for Allegheny Ludlum Steel Corp. But, certainly, the pooling of the two groups of skilled technicians, one with a history of chemical processing and the other of metallurgy and metal processing, has been beneficial. Much of the success of Titanium Metals Corporation of America can be ascribed to this cooperative, or joint, venture. TMCA was the first joint venture in the titanium industry, and of the

3 other companies now actively selling mill products, 2 of them are similar joint ventures of companies with complementary skills.

"In 1950 only about 50 tons of titanium sponge was produced, of a quality intolerable today. In each of the following years, production just about doubled that of the previous year. And, such is the steep pitch of such a geometric progression that in this year of 1956 total industry production of sponge may approach 15,000 tons. For 1957, a further doubling to 30,000 tons could be supported by estimates of market demands, but actual output probably won't reach that figure. There just comes a point in any such geometric progression where doubling and redoubling imposes severe strain on technical manpower and available money.

"SPENDING 20 MILLION IN YEAR

"In 1950, TMCA had 1 employee, today it has over 1,000 direct employees, and many more indirectly working in the fabrication of titanium products. In 1950, TMCA—or more rightly its two parent companies—committed $15 million to the titanium venture. In the 1 year of 1956, TMCA will have committed somewhere between $20 million and $25 million on production and allied facilities.

"You might consider such a dramatic development as being just another example of evolution from laboratory to full-fledged industry in the classic American tradition, where skills and money are poured into a promising area and a market is developed as know-how increases and prices are reduced. However, I do think that titanium stands alone—certainly in the metals industry—in the extreme rapidity and nature of its evolution.

"Not always has the titanium industry seemed so promising as it is today. Of course, to the technical man and the military designer, it has for years been the metal of their dreams. This metal is highly corrosion-resistant, it is potentially capable of strengths exceeding heat-treated alloy steel, and its weight is barely half that of steel. Further, there is considerable evidence that it can operate at high stress levels at temperatures up to 1,000° F. Here is a metal without peer for the new age of gas turbines, near sonic and supersonic flight, high-performance aircraft, ballistic missiles, the corrosive environment of atomic installations, and the multiplicity of extreme corrosive conditions which characterize today's chemical-processing industry. To the technical man and the military planner must go the credit for much of the early enthusiasm and push of titanium development.

"DESPONDENT USERS

"But, to industrial management which must furnish the plans and the money, the titanium venture had many forbidding aspects—so forbidding that only a few decided to press ahead. These men saw a metal in its very infancy of laboratory development, faced with the necessity of expanding into large production units without the slow, safe pacing of prototype and pilot units. The metal was exceedingly expensive, and was produced by a complex procedure which most observers claimed to be far too cumbersome ever to achieve reasonable costs or quality. The users of metals were despondent about the

virtual impossibility of machining, grinding, welding, or forming the metal. Furthermore, initial applications of the metal were in the jet engine and airframe industries, where design values soar to the very limit of what is in a metal, and specifications are unbelievingly rigid as compared to ordinary commercial standards. And, to further give pause, the entire market for some years seemed tied to military requirements, which are subject to shift and change beyond the control or influence of the industrialist.

"At the outset titanium defied any orderly market analysis by conventional methods. In fact, those companies that attempted such analysis were probably so depressed by the results as to shy away from a commitment.

"Our associates in Allegheny Ludlum have a history of early entry into new products, and I believe that National Lead also is known for its prompt and energetic exploration of new fields of activity.

"So, the two of us kindled to the enthusiasms of our technical groups, and we stepped off with the first integrated titanium activity. Our interests spread from ore to finished mill product. In fact, we are still the only company involved in the recycling of all byproducts, one phase of which makes TMCA the second largest producer of magnesium in the United States, every pound of which is constantly reused within the titanium production cycle.

"By the end of 1957, TMCA will not only be the country's second largest producer of magnesium but will likely be the world's second largest producer as it recycles an even greater quantity of this metal to produce 9,000 tons of titanium sponge per year.

"DOMINANT PROPERTIES

"Both National Lead and Allegheny Ludlum were, and are, constant in their conviction that titanium is such a desirable metal, with so many dominant properties, that competitive stature with the other three engineering metals—steel, aluminum, and magnesium—is a legitimate target. We realize that security in the nonmilitary field depends on prices considerably lower than those prevailing today, and we are bending every effort to progressively reduce prices. TMCA has, and is, devoting great sums of money and much technical skill to perfect other means of basic extraction, electrolytic for instance. But, at the outset, and also today, we have the opinion that the somewhat disdained Kroll method of reduction enjoys long-term capability of turning out the very highest quality of metal at quite low cost.

"Therefore, to summarize, we believe the titanium industry to be well along its steep trend line of development. However, it is now, and for several years will remain, in a ferment of evolution and expansion, which should greatly broaden its technical base and open the way into areas of cost and customer pricing certain to attract an increasing number of nonmilitary applications.

"PRICE PICTURE

"Already the industry has established an enviable reputation for price actions, particularly striking in that all such reductions were made when visible supplies of metal were sold for many months ahead, with resultant lack of customer pressure. In the basic sponge, the price hung at its orginal $5-per-pound level up through the early part

of 1954. Then, on April 1, du Pont dropped the price to $4.72, and, in December of the same year, further reduced the price to $4.50. On April 1, 1955, TMCA chewed off 55 cents per pound, thereby establishing a new price of $3.95, and on November 1, 1955, du Pont dropped 20 cents further to $3.75, and barely 3 weeks later TMCA cut 30 cents more to make a price of $3.45 per pound. Then on May 15, 1956, TMCA went down 20 cents to a new price of $3.25, and in mid-1956 du Pont went down to $3 per pound.

"This 40-percent reduction in sponge price within a space of 2 years is a steeply pitched downward trend line with few, if any, parallels in the metals industry. You may note that du Pont initiated 4 of the declines, whereas TMCA initiated 3, although the total of TMCA reductions was the larger.

"Since mill products are further along the production cycle than sponge, it is only to be expected that changes in the price of mill products will lag behind changes in the price of sponge. In February 1954, TMCA announced some scattered price declines for certain mill products, and on April 1, 1955, declines of $1 to $3 per pound were announced. On November 23, 1955, further cuts ranging from 60 cents to $3 per pound were made, and in May 1956 various mill products went down 6 percent more. All of these reductions were initiated by TMCA.

"All this price action is the result of the first upward surge of the titanium industry, from laboratory to routine production of rather sizable quantities of metal. But, now, the industry is moving into a second stage of development, with total production capabilities moving to far higher levels along paths of greater efficiency, and with processing of the metal shifting onto equipment specifically designed for titanium. This later trend will certainly have dramatic effects on the quality of products and on recovery, and all this will in the future assure even more widespread usage of the metal and should reflect in a continuation of the downward price trend.

"VACUUM MELTING

"The very large, very efficient and very precise consumable-electrode vacuum-melting ingot furnaces developed by Allegheny Ludlum for melting titanium are already being adopted by the steel industry for melting premium alloys. I venture to say that the extensive and unique vacuum-annealing and vacuum-degassing furnaces devised and regularly used by the titanium industry will find equal favor with other sections of the metals industry in the near future. On January 10th of this year, TMCA purchased a $3 million Senzimir reversing cluster mill for the cold rolling of continuous bands of titanium sheet in widths up to 49 inches. This is the first such mill to be altered to accommodate the peculiarities of titanium, and its operation in a few more months will assure wide, thin and close-tolerance sheets for use in the airframe industry.

"The entire industry is in the initial stages of developing the metallurgy and production techniques for heat-treated alloy sheet, of strength levels far above anything produced in the past, and in sizes and gages not obtainable even in steel today. Here again, many new machines and processes have been and are being piloted. Special heating furnaces, different rolling procedures, hitherto unknown rigs for heat treatment of very large sheet and special flattening devices,

are all passing through the prototype stage into full-scale production machines. Here again the titanium industry will end up with procedures and equipment which will be borrowed in whole or part by the metal industry in general."

[New York Times, October 26, 1956]

Titanium Industry To Get Its First Processing Mill

The Titanium Metals Corporation of America announced yesterday the purchase of a plant at Toronto, Ohio, 60 miles west of Pittsburgh, for conversion into what the company said would be the first specialized facility in the Nation for rolling and forging titanium. Until now, the titanium industry has depended on steel mills to convert titanium ingots into mill products.

The company, a large producer of titanium metal, is owned jointly by the National Lead Co. and the Allegheny Ludlum Steel Corp. Titanium Metals said it was buying from the Louis Berkman Co. its Ohio River steel division plant at Toronto. The plant has 400,000 square feet of floor space and 50 acres of property.

Establishment of the processing facility, the company said, will mark the first effort to handle separately the more demanding requirements of high-strength titanium alloy products. The first items from the plant will be special forged billets for jet engines and heat-treated alloy sheets for jet fighters, bombers and missiles.

Special rolling mills, furnaces and heat-treating equipment are in the design or construction stage for the plant, requiring an expenditure of about $8 million.

The company said it would continue its policy, announced previously, of paying for new facilities with its own resources, without Federal assistance.

The company announced recently an expansion of its Henderson, Nev., plant's titanium sponge capacity from 6,000 to 9,000 tons a year and an 80 percent increase in titanium ingot capacity, to 11,000 tons a year. Titanium sponge is a primary form of the metal that must be melted into ingots.

Early this year the company reported the purchase of a $3 million cold rolling mill for continuous processing of 48-inch titanium sheet to the exacting measurements demanded by the airframe industry.

The expansion, the company said, reflects the rapid growth in demand for titanium metal.

[American Metal Market, September 12, 1956]

Titanium Progress Outlined by F. C. Frary at New York University

New York, September 11.—The College of Engineering, New York University, yesterday opened a significant course, running for 1 week, on the metallurgy of titanium. The first lecture on the status of development was presented by Francis C. Frary, of the National Research Council.

Due to illness, Dr. Frary's survey was presented by Prof. Herbert C. Kellogg of Columbia University.

Among the features stressed by Mr. Frary were:

1. Much work is still to be done before titanium can take the place it deserves in the world's metal economy. The greatest part of the development is being done in the United States.

2. No other metal has ever seen the production acceleration as has this new metal. It is mainly used in defense but civilian uses are developing.

3. Titanium retains a good portion of its strength at 800° F. Aluminum and magnesium lose strength rapidly above 400° F.

4. Because titanium is about 40 percent lighter than steel it is of vital importance where saving of weight is required.

5. The demand is climbing and this year's sales should double those of last year.

6. The supply of titanium sponge is adequate and much is being learned about the melting and other techniques.

7. There are four large producers plus several pilot plant operations. Two companies are also working on an electrolytic process and the Bureau of Mines is also doing work in this category.

8. Production operations must be carried out in a vacuum or in an atmosphere of some inert gas. Melting and casting require the same atmosphere.

9. Speed in heating and working is required. Alloy development is still in its infancy.

10. Much engineering information is still to be obtained. Production of extrusions is particularly difficult. Much is still to be learned about fabricating practices.

In his lecture at New York University, he stated in part:

"Titanium is the newest of the 3 structural light metals, also the strongest and heaviest, and has the highest modulus of elasticity. It is also (and probably will continue to be) the most expensive of the 3, and the most difficult to fabricate and shape into finished articles, such as airplane parts. Nevertheless, the supreme importance of weight reduction in aircraft and some ordnance items, and the development of supersonic speeds in military planes have made its availability very important. Consequently, the Government has spent many millions of dollars, and will continue to spend more for a considerable period, on research and development projects concerned with the production of this metal, its fabrication, and the engineering information needed for its correct and efficient use in aircraft and ordnance. Its great resistance to chemical attack by most acids, alkalies and salts gives reason to believe that it will also eventually have an increasing use in the chemical industry and in marine engineering.

"While titanium is inert and noncorrodible by most reagents at ordinary temperatures, this inertness disappears at higher temperatures, and at the production and fabricating temperatures the metal avidly combines with even traces of oxygen and nitrogen. The molten metal reacts with all the common refractory crucible materials, and most (if not all) of the uncommon ones. Such materials always contain oxygen, nitrogen, or carbon, which have a great affinity for titanium, dissolve in the molten metal, and harden it greatly if present in even small fractions of 1 percent. This is a basic difficulty, involving

both equipment and operating expense, in both production and fabrication processes."

[American Metal Market, August 16, 1956]

Large Expansion for Titanium Is Planned by TMC

ANNUAL USE IN 1958 IS ESTIMATED AT 15 MILLION TONS

New York, August 15.—National Lead Co. and Allegheny Ludlum Steel Corp., parent companies of Titanium Metals Corp. of America, today announced a further expansion of titanium metal production capacity at Henderson, Nev. Output of sponge is to be increased 50 percent and related melting facilities for the production of titanium ingots are to be expanded 80 percent.

This program follows closely the announcement in March of this year of a 67 percent increase over the original plant output of 10 tons per day. When both programs are completed late next year, the total capacity of the Nevada unit will be 25 tons of titanium sponge per day or 9,000 tons per year, and 30 tons of titanium ingots per day or 11,000 tons per year. Included will be an entirely new melt shop unit for the production of ingots designed to permit further expansion of capacity in the future. The overall cost of the additional facilities is estimated to be $15 million.

This latest expansion reflects the rapid growth in demand for and consumption of fabricated titanium which has taken place in the last 12 months. Estimates made earlier this year of potential demand of titanium for 1957 and 1958 have now been revised upwards on the basis of recent Government and industry studies. Total annual consumption of titanium by 1958 is now estimated at 30 million pounds of finished mill products compared with a total of less than 4 million pounds in 1955. Important in the stimulation of increased usage have been the series of price reductions which the company has effected in the past two years and the improvements in the quality of the products to meet the exacting technical requirements of the jet aircraft, engine and guided missile industries.

Continuing the policy announced earlier this year, Titanium Metals Corporation of America will pay for the new facilities from its own resources without Government assistance.

Titanium ingots produced at Henderson are processed into mill products in the plants of Allegheny Ludlum for TMCA. A number of new installations of processing equipment, some of which must be especially designed for titanium, will be required to permit the processing of the new output of titanium ingots.

The two companies disclosed that earnings for the first half of 1956 for the 6-year-old Titanium Metals Corporation of America totaled $5,205,000 after taxes (subject to year end and audit adjustments). For the full year 1955 earnings were $7,161,000 against $1,572,000 in 1954. No dividends have been paid by TMCA to parent companies up to this time and the earnings shown above have not been consolidated with the figures reported by National Lead and Allegheny Ludlum. While TMCA has made sales which are subject to renegotiations, the corporation is of the opinion that no provision for possible refund is required.

[American Metal Market, August 15, 1956]

Report Presents Details on Pilot Plant Cost of Producing Titanium Sponge

Pittsburgh, August 14.—Detailed costs of producing nearly half a million pounds of titanium sponge metal in a Government pilot plant at Boulder City, Nev., are given in a Bureau of Mines report released today by the Department of the Interior.

The information, accumulated during 15 months of continuous operation of the pilot plant, can be used by present commercial producers for comparative purposes and by potential producers as a basis for cost calculations. The pilot plant ceased operations in the fall of 1954.

The report details the costs of various items, not only citing actual expenditures for each, but also giving the prices and wage rates prevailing at the time. It also describes plant equipment and presents information on the quantity of raw materials and supplies used, the number of man-hours worked by persons in various job classifications, and the basis on which overhead and maintenance costs were figured. In addition, it includes detailed time studies of the various production steps in using the magnesium-reduction process.

The pilot plant was built as a research facility for improving titanium-production methods. The report, however, is based on its operation as a production unit under a contract with the Defense Materials Procurement Administration, later taken over by the General Services Administration. At the time, fast-growing defense needs were threatening to outstrip industrial production of the strong, lightweight metal.

C. T. Baroch, chief of the Titanium Development Section of the Bureau's Region II at Boulder City, and T. B. Kaczmarek, formerly a metallurgist in that section, prepared the report.

A copy of Report of Investigations 5248, "Titanium Plant at Boulder City, Nev.: Operating Costs," can be obtained from the Bureau of Mines, Publications-Distribution Section, 4800 Forbes Street, Pittsburgh 13, Pa. It should be identified by number and title.

TITANIUM RESEARCH REPORTS

Three reports of research on titanium alloys—1 on weldability, 1 on scaling, and the other on their preparation for chemical standards—have been prepared for the Air Force and released for industry use through the Office of Technical Services, United States Department of Commerce.

Evaluation of High Strength Weldable Titanium-Base Alloys. C. R. Lillie, Armour Research Foundation for Wright Air Development Center. December 1955. 62 pages. $1.75. (Order PB 121069 from OTS, United States Department of Commerce, Washinton 25.) Six Ti-Al-V alloys were investigated for suitability as high strength weldable sheet with utility at high temperatures. All provided sheet material capable of heat treatment to a strength-weight level competitive with stainless steel. The alloys were weldable and good formability was indicated. Favorable properties were retained after preparation with commercial quality sponge material and heat

treatment at commerical standards. The best compositions lay in the range of Ti-4 Al-4 V to Ti-6 Al-4 V.

[American Metal Market, May 30, 1956]

Titanium Firm at Burbank, Calif., Enlarging Plant

Los Angeles.—Titanium Fabricators, Inc., Burbank, Calif., is expanding its plants and production facilities to meet the increasing demand for titanium in commercial and military applications, Fred Spiegl, president, told a stockholders' meeting, first since the company completed its public stock offering.

Titanium forged parts are replacing stainless steel and aluminum alloys in aircraft applications, such as tailpipes, nacelles, etc., he said. He predicted wider use of the metal.

Titanium Fabricators was founded in February 1955 to provide research, development and production for scientific fabrication of titanium and other metals.

[American Metal Market, May 4, 1956]

Large Titanium Tetrachloride Unit Now in Operation

Pittsburgh, May 3.—One of the largest titanium tetrachloride plants in the United States has been placed in operation by Columbia-Southern Chemical Corp. at Natrium, W. Va. The new plant is situated on the Ohio River and is integrated with Columbia-Southern's large chlorine producing plant.

According to E. T. Asplundh, president, the plant will have an annual production capacity of 35,000 tons. Basic process design of the plant was by Columbia-Southern and the engineering and construction program was completed by Catalytic Construction Co. of Philadelphia.

Construction of the multimillion dollar facility was accomplished in less than 12 months and the intial shipments of titanium tetrachloride are ahead of the original time schedule.

Titanium tetrachloride is a clear liquid used by titanium metal producers in a chemical process to produce titanium sponge. In the production of the product, chlorine is reacted with a titanium-bearing ore in specially designed equipment.

This reaction of the metal ore and chlorine gas produces a crude grade of titanium tetrachloride which requires several purification steps to yield a high purity titanium tetrachloride as a clear liquid. Titanium tetrachloride of highest purity is required to meet the demand for higher quality metal.

Liquid titanium tetrachloride is reacted with another metal in liquid form to produce titanium sponge.

During the late 1930's, Columbia-Southern initiated research work on the chlorination of various titanium-bearing ores. This work, it is believed, has made it possible for Columbia-Southern to obtain the most economical and practical means of titanium tetrachloride production. The initial research work resulted in the development of a basic patent position in the titanium tetrachloride field, and has contributed significantly to the commercialization of titanium metal.

During World War II, Columbia-Southern provided commercial quantities of titanium tetrachloride to the Government for military purposes.

[American Metal Market, April 28, 1956]

Titanium Seen Making Headway In Aircraft Parts

BELL'S KAPPELT SAYS IT IS STRONG COMPETITOR FOR STAINLESS

Buffalo—An elaborate survey on the fabrication of commercially pure titanium in aircraft construction was presented recently by George Kappelt and A. E. Leach of the Bell Aircraft Corp. of Buffalo at a special conference on titanium and other reactive metals sponsored by the American Institute of Mining and Metallurgical Engineers.

In presenting the study, Mr. Kappelt detailed how the characteristics of this new metal differ from those of other metals and alloys. He pointed out that pure titanium may be a successor to 18–8 stainless steel for many applications because it has all the requirements for nonstructural service in temperatures up to 800° F. and has the added advantage of a lower weight.

In the conversion from stainless steel to titanium to reduce weight in parts for the B–47, Bell has purchased more than $8 million worth of the new metal and has fabricated thousands of titanium sheet parts. He said that many problems have been solved and while new ones will be coming up, "we feel that the worst is over and titanium is well on the way to being tamed." He pointed out that under special conditions, highly ductile fusion welds can be made with titanium. He said that the new metal would give strong competition to stainless steel for many aircraft applications.

The main text of the study by Mr. Kappelt and Mr. Leach of Bell Aircraft Corp. follows:

Much of our forming is done hot and several means of heating metal blanks are now in use. A portable, air circulating oven is used which can heat blanks to a temperature of 750° F. It can be moved about the shop from press to press and is versatile enough that it can be used for almost any kind of hot forming. It has the obvious disadvantage that blank heat-up time is long. Sometimes portable platen heater is used.

A resistance heater is expected to be used for much of our blank heating in the future. This piece of equipment is relatively new to our shop and has not been fully evaluated but it has many advantages. Heating is rapid and uniform and there is a minimum of lost time and wasted power.

Wrapping brake press formed channels to a circular shape is a common method of forming in the aircraft industry. This is done on a stretch press.

STRETCH FORMING

In stretch forming sheet contours nonuniformities within individual sheets become especially noticeable. Most stretch formed sheet parts require planishing (hammering) to some degree after stretch forming to eliminate these nonuniformities. In some cases, heated

form blocks have been used for especially tough contours. Temperatures of 300-350° F. give a remarkable improvement in the stretching characteristics of commercially pure titanium.

The drop hammer is always the reliable workhorse in forming aircraft sheet metal parts. It is versatile and is used in many ways in the fabrication of titanium.

Many parts are formed completely in the drop hammer.

SEVERE DIE WEAR

Die wear in the drop hammer is severe because of the elevated temperatures and the peculiar galling characteristic of titanium. Steel inserts have been found useful in prolonging die life.

We have two drop hammer punches for all titanium parts. One is a working or roughing punch while the other acts as a coining or final stage punch. The final stage punch replaces the working punch when the latter becomes worn beyond usefulness, and a new final stage punch is cast.

The drop hammer is also used as a finishing tool to set the contours of parts formed by other means. In this respect it merely replaces hand finishing.

Because the flow of metal during forming cannot be readily controlled in the drop hammer, parts which have areas of extreme shrink are formed in double-action crank or hydraulic presses using electrically heated steel dies. Press dies are usually heated because of the comparatively long forming time for this type of operation.

A heated steel die set up in a crank press is sometimes used. Blanks are preheated to about 600° F. in an oven or resistance heater and dies are maintained at about 400° F. The part has two shrink flanges and is a good illustration of a part which can only be formed hot. At room temperature these flanges would at least be badly wrinkled and probably torn and the dies would be useless after only a few parts.

LUBRICANTS

It may surprise some of you to hear that we are using a petroleum oil as a drawing lubricant, even for hot forming. Though it tends to burn, it still provides good lubricating action during a short forming stroke. Silicone oils are more heat resistant but have practically no lubricating power. Graphite and molybdenum disulfide are good lubricants and have the best heat resistance, but collect in the corners of dies, making frequent die cleaning necessary.

Under ideal conditions, highly ductile fusion welds can be made in commercially pure titanium. However, attaining these ideal conditions in the shop is not a simple matter, and for this reason titanium must be rated "weldable with difficulty." We have constructed a box which represents a compromise with shielding requirements and the necessity of a practical shop procedure. It has a glass top, the side is hinged and there are access holes for torch leads and hands.

Parts are inserted through the side and the box is purged with argon gas for several minutes. The first weld beads are made on pieces of scrap titanium. This process is continued until there is no visible oxidation of the weld. Welding of parts is then begun. As long as not more than a few minutes elapse between stopping and starting the

arc, it is not necessary to reclean the atmosphere in the box by welding on scrap titanium. However, with each new load of parts this must be done. Fusion welds made in this manner have ductility approaching that of the base metal.

EASILY SPOT WELDED

Commercially pure titanium is easily spot welded over a wide range of machine settings. Nuggets develop excellent shear strength and usually have "nugget pullout" failures in the shear test. We ran an extensive program to determine correct machine settings, which were found to be roughly the same as those used in spot welding 18–8 stainless steel.

An illustration of the worst problem in forming titanium was cited. It shows two parts made in the same dies, using identical procedures, but two different lots of titanium. They are supposed to have 90° flanges. One of the parts formed about the way it should but the other flange sprang back about 45°.

The variable springback of titanium is our most severe problem and a discussion of what we are doing about it is our principal topic this afternoon.

Plotted data showed calculated springback versus yield strength for titanium and stainless steel for forming under these conditions—sheet thickness 0.030 inch, tool radius 0.5 inch, and forming angle 90°. Annealed 18–8 stainless steel will spring back between 9.5 and 11°, one-fourth hard between 13 and 15°, and one-half hard between 18 and 20°. This springback variation would not even be noticed in fabrication.

In comparison, commercially pure titanium, with a yield strength spread of about 70,000 to 105,000 pounds per square inch, will spring back between 22 and 31°.

Because the shop characteristics of stainless are so well known they provide a good reference standard. Also, titanium is giving it strong competition for aircraft applications and the same general types of parts are being made of both materials.

[American Metal Market, April 25, 1956]

Planes, Missiles To Spur 1957 Call for Titanium

Washington, April 24.—Reports of aircraft manufacturers and titanium fabricators indicate a rising trend in the use of the metal for plane and missile applications with a definite acceleration of demand forecast for 1957.

A number of fabricators and manufacturers expect balance in sponge supply and demand for 1956 but the mapority are concerned about the availability of the metal beginning next year.

Their views are expressed in a forthcoming progress report on the titanium situation by the Senate Committee on Interior and Insular Affairs.

The report will show that the emphasis throughout the titanium industry is now on the improvement in quality of mill products.

The Air Force directed in August of 1955 that the military aircraft designed be encouraged to use titanium where feasible. The Air

Force expressed the hope that the improvement in quality of mill products during the past 6 months will influence the use of additional quantities of titanium.

The Department of the Air Force reported to the committee that on the basis of current requirement estimates it appears that sponge production for 1956 will be sufficient to meet demand.

The memorandum said: "The Air Force believes that a sufficient margin of safety must be provided in sponge production to compensate for new uses as they develop. This is particularly important until such time as military applications are proven, the cost stabilized and the potential of this metal more adequately determined.

"A margin of 100 percent of sponge production, in excess of equivalent estimated mill product use, should provide adequate safety, permit the orderly expansion of the industry and yet reasonably limit the obligation of the Government."

EXPERIMENTAL WORK

The Air Force disclosed that negotiations are now underway for additional titanium experimental projects totaling $1,725,000. Six projects at a cost of over $4½ million have been negotiated by the Air Force.

The Department of Defense reported that a directive has been issued ordering the use of titanium "rather than cheaper alternate materials."

The use of titanium in the airplanes that follow those now entering production "will be very large," a leading military plane producer predicted. "The availability and the quality of present sheet, bar, and billet must be improved, however, for such large-scale use in aircraft."

[American Metal Market, April 22, 1956]

TITANIUM SPONGE PRODUCTION STARTED AT NEW ELECTRO METALLURGICAL PLANT

ASHTABULA FACILITY, PRIVATELY FINANCED, USES SODIUM PROCESS AND WILL HAVE CAPACITY OF 7,500 TONS PER YEAR

ASHTABULA, OHIO, April 26.—The first heat of titanium metal sponge at the new Ashtabula plant of Electro Metallurgical Co., a division of Union Carbide & Carbon Corp. was completed here today.

The heat produced by the sodium-reduction process marks the entry of Electromet into the titanium metals sponge field on a commercial scale.

The plant which has a capacity of about 7,500 tons of titanium metal sponge a year is the largest built to date and was privately financed by the company. The new plant is located on the Lake Erie site of Electromet's plant for the production of ferro-alloys and calcium carbide at Ashtabula.

NEW PROCESS USED

This is the first commercial production of titanium sponge in the United States by a method other than the magnesium-reduction proc-

ess. In Electromet's process sodium is used to reduce titanium tetrachloride, resulting in metal of high quality. Economic and technological considerations led to the commercial development of the sodium reduction process, after extensive studies of other reduction methods. The company has had this process in operation on a pilot and prototype plant scale at its metals research and development laboratories in Niagara Falls, N. Y. The titanium sponge produced by Electro Metallurgical Co. is remelted into ingots by producers of titanium mill products and commercial shapes.

The new titanium process has been the subject of research and development for more than 6 years at a cost of over $2 million. Actually, Electromet has conducted research on various methods for the production of titanium for almost 15 years, and has been regularly producing alloys of titanium for over 20 years.

OUTPUT INCREASING RAPIDLY

Titanium sponge has had a spectacular growth from a mere 3 tons in 1948 to 7,200 tons in 1955, and an estimated 13,000 tons this year. The Electromet plant is expected to reach rated capacity of 7,500 tons per year by the fourth quarter of 1956.

[American Metal Market, April 5, 1956]

TITANIUM BOLTS WILL BE USED ON TWO NEW TYPES OF JET PLANES

PHILADELPHIA, April 4.—Major orders for titanium bolts received by Standard Pressed Steel Co., from two leading aircraft makers and approval of SPS titanium fasteners by a third company and by the Navy indicate that the titanium application is picking up more steam in the aviation industry.

The Jenkintown (Pa.) precision fastener company reports that Glenn L. Martin Co. has ordered $200,000 worth of its Hi-Ti fasteners for use on the Navy's new SeaMaster jet bomber and that Chance Vought Aircraft, Inc., has also ordered a sizable quantity of the titanium bolts for the Navy's supersonic jet fighter, the Crusader.

At the same time, it was revealed that the firm had just been approved as a source for high-strength titanium shear bolts by Boeing Airplane Co., and that the Navy Bureau of Aeronautics had just completed satisfactory laboratory tests of titanium tension and shear bolts.

These developments follow a $650,000 order for titanium bolts for an Air Force plane received late last year by SPS from the Convair division of General Dynamics Corp.

Chance Vought's F8U1 Crusader, unofficially said to have reached speeds in excess of 1,000 miles per hour in flight, is billed as the world's fastest Navy jet fighter. Martin's XP6M–1 SeaMaster is the world's first multijet seabased bomber.

The titanium fasteners, which weigh 43 percent less than the steel bolts they replace, will permit significant weight reductions on both the Crusader and the SeaMaster.

Until early in 1955, when SPS demonstrated the feasibility of producing high-strength titanium bolts as sound as their steel counter-

parts, little, if any, titanium had been used in critical fastening applications.

During most of last year, when leading airplane makers and Government agencies such as Wright Air Development Center were running evaluation tests of the new fasteners, SPS produced titanium bolts only in qualification lots. Output was measured in pounds. This year, production is being measured in tons.

The Convair Chance Vought and Martin orders plus sales of titanium bolts and other parts in qualification lots to more than a dozen other leading companies have put a total of $1,500,000 worth of titanium business on the firm's books. The company sees good prospects for additional major orders in the near future from weight-conscious airframe and aircraft engine fabricators.

[American Metal Market, August 4, 1955]

Chromium Coating May Help Lift Use of Titanium

TIARCO METHOD SUCCESSFUL IN SPECIAL PISTONS FOR A DEFENSE WEAPON

New York, August 3.—The coating of titanium with chromium by the new Baylig process is likely to have some important future applications. The new process has been developed by Tiarco Research Laboratories of Clark, N. J., and it may help to increase some uses of titanium.

Paul J. Topelian, director of research at Tiarco, points out that the new chromium coating should prove valuable because titanium has a tendency to gall, especially where sliding contact is involved. He emphasizes many high credit marks for the new metal but also cites a few of the debit marks. The chromium coating process will help to correct some of the latter.

At the research laboratories of Tiarco Corp., in Clark, N. J., chromium plated on titanium parts have been subjected to a great number of physical tests. To mention a few, strips of RC–70 titanium were chrome plated to a thickness of over two thousandths on the side and then given the above-mentioned reverse-bend test. There was no chipping or peeling of the deposited chromium. Another severe test was repeatedly hitting a plated piece of titanium with the edge of a hammer. The marks of the blows were quite visible but the chromium followed the indentations without cracking.

Tiarco Corp. states chromium is one of the slipperiest metals known. It has one of the lowest coefficients of friction among all metals. It is one of the hardest metals known; actually on Mohs scale of hardness where the number 10 is given to the diamond, chromium is 9.1. It is also very highly corrosive resistant to most chemicals and atmospheres. Truly an excellent partnership titanium and chromium—one offsetting the other in each others possible weaknesses. And this is precisely where the Baylig process (patent pending) comes into the picture. The process actually puts a very dense deposit of chromium directly on all titanium and titanium alloys. There are no intermediate coatings of other metals to set up possible electrolytic actions between dissimilar metals. Chromium is one of the most passive metals known.

"A piece of titanium, 150–A, 4 inches long and one-half inch in diameter was chrome plated by the Baylig process. It was then subjected to a buffing wheel with polishing compound traveling at a very high rate of speed. The piece was held to the wheel for almost 5 minutes on one spot. It naturally became exceedingly hot, but there was no 'giving away' of the chrome. In fact, a mirrorlike finish was the result with exceptional smoothness."

Buffalo Arms has reported exceptional high performance of special chromium-coated pistons for a defense weapon. There was no chipping under high heat and sharp abrasion.

The Buffalo firm has stated:

"The two pistons are still in the weapons as of July 25. Although they are not fired daily, a very good sign of the durability of the Baylig process on titanium has been evaluated. We are not at liberty to say what percentage has been reached in the expected endurance of this component. But with the known results so far, we can point with honest pride to the fact that 3 years of persistence and determination to achieve our goal was not wasted."

Columbia-Southern and London Firm Submit Titanium Plan to United States

Pittsburgh, August 3.—Columbia-Southern Chemical Corp. of Pittsburgh and Imperial Chemical Industries, Ltd., of London, England, have submitted a joint application to the United States Government for a contract under which the Government would undertake for a 5-year period to purchase 5,000 short tons per annum of granular titanium metal.

In their application to the Government for a contract, the companies have stated that they have completed arrangements for the introduction into the United States of a granular titanium process not at present employed here and would also make available to fabricators techniques not at present known or employed in the United States.

If a contract is awarded in pursuance of their application, Columbia-Southern Chemical Corp. and Imperial Chemical Industries, Ltd., will form a jointly owned subsidiary for the purpose of producing titanium metal by ICI's sodium-reduction process. The parent companies will each hold a 50-percent interest in the new company, which would be known as Columbia Titanium Co. The plant would be built at Natrium, W. Va., and would have a capacity of 5,000 short tons per annum. The cost of the proposed granular titanium metal plant will be approximately $10 million.

ICI's patent position and production experience have an unusually broad base through their experience of chemical and metallurgical technology. Their patent and process knowledge extend from the production of granular titanium metal by their new sodium process, to melting, scrap recovery, alloying, testing, joining. and fabrication, in the latter of which particularly they are favorably placed by virtue of their wide experience in nonferrous metal technology.

Columbia-Southern's contribution to the proposed joint enterprise lies in the field of titanium tetrachloride production. Columbia-Southern, which is one of the leading American producers of chemical

products and is a wholly owned subsidiary of the Pittsburgh Plate Glass Co., has been engaged in research on the chlorination of titanium-bearing ores since 1937. It has established a broad patent position in this field and today licenses other companies under Columbia-Southern patents.

Columbia-Southern and ICI believe that their proposal to the Government will result in lower capital and production costs and in the aceleration of a titanium fabrication industry in the United States.

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